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GENERAL SESSIONS

President's Report

WILFORD Y. CANNON[1]

In the 4 years since the last meeting of the Society, our country has fought the greatest war in history. We have seen our sons and relatives go to war—many never to return. We have seen science marshaled for war work as never before. We have seen scientists by the score working on one small segment of a problem and, when the parts were joined together, some of the greatest inventions and discoveries of all time were the result. There never has been in the history of mankind the teamwork among scientists and scientific workers that there has been in the past 4 years. This work was integrated so that our armed forces were given the new tools, machines, and arms which made our own forces and those of our allies successful.

It is probably not out of order to suggest that this Society can be the integrating medium for piecing the parts together on which sugar beet scientists are working, thus bringing to a fruitful conclusion the problems which confront us.

Let us, therefore, review some of the past and see if some problems of the future can be outlined.

It is now 10 years since the American Society of Sugar Beet Technologists was organized at Fort Collins. This was one of the most important steps ever taken for the benefit of the industry. The wealth of material along the different lines, as outlined in our program, is the proof of the need for such an organization. The group of men who promoted this organization deserve the gratitude of all of us who are today being enriched in our ideas, for their vision of the necessity for such an organization.

In Genesis, third chapter, when Adam and Eve were cast out of the Garden of Eden the Lord said to Adam, "In the sweat of thy face shalt thou eat bread." We have been castigated by our critics so that the general public view is that this statement applies especially to the beet sugar industry. One of the aims of this Society is to improve the methods of growing beets so that this statement will in no way be true.

Starting in 1898 there was a tremendous upsurge in the development of the beet sugar industry and the building of sugar factories. On July 25, 1897, a tariff was established on raw sugar, of $1.685 per hundred weight. There were nine factories in the United States at that time. In the next 5 years this number increased to 53. Factory extractions were low, being approximately 70 percent on beets bought. Beets were purchased for $3.75 per ton. In the beet contract which

[1]Production Manager, Utah-Idaho Sugar Company, Salt Lake City, Utah.

the grower signed with the sugar companies please note that it was stipulated that beets must not weigh over 3½ pounds each. In the area with which I am familiar beets were hauled in ordinary wagon boxes and were carrot-like in size. Sugar content of beets ran from 13 to 14 percent. Sugar prices were $5.00 per hundred pounds as compared with $5.40 at the first of this year. Factory efficiencies have been improved. The price paid to the grower has multiplied. We now take beets much larger than 3½ pounds and like them. Sugar content of beets is much higher. But the price of sugar is almost the same as it was 48 years ago. We have probably made the major improvements in factory operations that are possible. If the industry, therefore, is to survive and be prosperous we must find ways to lower the cost of growing beets. This can be done by mechanization and increasing yields.

The beet sugar industry has proved its value to the agricultural areas in the United States. Reclamation projects which have sugar factories in the neighborhood have become prosperous. Good schools, fine homes, churches, and roads have been built. Fattening of sheep and cattle has become a major enterprise in these areas.

Markets have been developed for automobiles, farm machinery, and household appliances. Coal mines, lime quarries, and railroads have benefited. Employment in rural communities has been stabilized.

No successful sugar company manager or fieldman will recommend that more than 20 to 25 percent of the individual farm be planted to beets, yet no other crop will improve farming practices as will sugar beets. Beets are a bread and butter crop; this crop keeps taxes paid; it pays off the mortgage. It is so important to our rural economy that it must thrive and improve.

During the 30 years I have been intimately familiar with the sugar business, the handling of beets by the sugar companies has been improved tremendously. At the time I started, the beets delivered to the factory were either forked into the bins or a hand winch hoisted up one side of the wagon and the beets were dumped into the bin. Rail points were provided with highline dumps with hand operated winches, or beets were forked into piles at the rail point. Then came the belt conveyors at factories, and power dumps at rail points. Then more recently came wet hoppers for rail beets, portable pilers for receiving beets at both factory and rail points. Storage piles are now reclaimed with equipment such as the Athey or Garner loaders. This now makes the handling of beets from the farmer's truck to the factory as efficient as any material handling in any industry known to me. The farmer's problem is not solved until he has reached this same efficiency.

In 1936, the year of the founding of our Society, the domestic beet seed business had just been established on rather a firm basis. The rapid expansion of domestic beet seed production built up during the first World War had practically died out. Then came the establishment of the over-wintering method of seed which was worked out in this country about 15 or 16 years ago. Under the spur of growers and processors the Division of Sugar Plant Investigation of the Bureau of Plant Industry, U. S. Department of Agriculture, had a good start on the development of beet strains resistant to curly top diseases. The past 10 years, which mark the Society's existence, have seen a development of seed varieties with a very high state of resistance to various diseases so that the domestic beet seed industry is on a firm foundation. There are still many problems which the plant breeders must solve. There is continuing improvement necessary in sugar content and purity of the beet. With the coming of mechanical harvesting it would be advantageous to improve the type of crown of the beet so that it will better lend itself to mechanical harvesting. Single-germ beet seed would be of tremendous advantage from a mechanization viewpoint. Our present methods of breaking down seed to approximately a single germ are very costly.

The mechanization of the industry has been talked about by both the grower and the manufacturer for at least 30 years. One of the first jobs that I had after starting to work for the Utah-Idaho Sugar Company was to make shop drawings for a beet topper. The topping principle, even at that time, would have been satisfactory if ways could have been found to harvest the beets. Because it did not solve the lifting problem the development did not meet farmers' approval.

It was shortly after the organization of the Society that the U. S. Beet Sugar Association, in cooperation with the University of California, started active work on mechanization of the beet crop. Probably the greatest impetus to Spring mechanization was the work that was done on the segmenting of beet seed and on single-seed planters. That fundamental work gave the incentive to a development which has been going on since, covering accurate spacing of the seed ball in the row and the lessening of the hand labor in the thinning operation. It also gave momentum to mechanical blocking experiments such as down-the-row, or cross, blocking. Where field germination was uniform it made possible the actual mechanical thinning of beets.

The work done at Davis, Calif., stimulated work on the mechanical harvester. Implement manufacturers were watching the development and after certain basic principles had been established these implement manufacturers started the development of machines in quantity production. Such harvesters as John Deere, Marbeet, International

Harvester, and several others have now reached a stage where they are actually harvesting beets in an acceptable manner under field conditions. Field loaders began to come into use several years ago, doing away with the forking of beets into wagons or trucks. Sishe, at Torrington, Wyo., did a lot of pioneering in this regard. Other manufacturers, using some of the principles he developed, continued the expansion of this particular phase of field loaders. Therefore, today there are several field loaders doing a very acceptable job.

Just about a year ago at Salt Lake City, representatives of the various sugar companies held a 3-day meeting on the problems of beet machanization. A survey was made of the work accomplished to date and a discussion of the problems still to be solved. This marked the beginning of the formation of the Beet Sugar Development Foundation, which was organized under the laws of Colorado in July of last year. Every beet sugar company in the United States is now participating in this organization. This Foundation should furnish the leadership for the completion of many of the problems which still confront us. I wish to make this statement, which I believe cannot be contradicted, that had it not been for the formation of the American Society of Sugar Beet Techonolgists, which brought industry and scientist closer together, this kind of cooperative effort would not have been achieved. This Society, through interchange of ideas, broke down many of the barriers between companies and caused a free discussion of mutual problems between its industry members.

I had a letter recently from one of our educational institutions asking if "Mechanize or Die" was not the situation facing the beet sugar industry. I do not know whether this is entirely so, but if we are to have a thriving industry it is certainly true.

There are still many problems confronting all of us who are working with all of our might to improve this industry. I do not think it possible to enumerate all of them in this discussion but some of them loom large. The elimination of weeds in beet fields is paramount before complete mechanization is attained. Even with perfect field germination and mechanical thinning, weedy fields still require a tremendous amount of hand labor. The cost of weed removal in weedy fields, even with mechanical thinning, is nearly as great as the cost of complete hand thinning.

This problem is so general that experimental work on chemical or hormone treatments for the elimination of weeds will be very worthwhile. Also those areas where the practice is used of plowing under a cover crop and then fallowing the land, have made very definite progress toward spring mechanization. This practice should be tried out on experimental bases in other areas.

The accurate placement of seed in the row has progressed faster than obtaining uniform field germination of that same seed. The field germination problem for study, therefore, involves a number of factors: First, conservation of moisture in the field; second, opening and closing of the seed furrow; third, placing seed down to moisture and then removing a layer of soil by mechanical means; fourth, covering the seed with an excess of soil which is removed after germination has started but before emergence of the plant. There may be many other methods open up as further study and research is carried on. This problem must be solved. Please bear in mind that the shoe or the disk opener with a press wheel following has been used for the placement of beet seed for at least the last 40 years without any particular change.

In the harvesting of beets the main problem yet to be solved is the separation of clods from the beets and the elimination of trash. The harvesters in use need further mechanical perfecting. There will probably be new methods or systems whereby tops will be harvested and hauled directly from the field. This will help solve the trash problem. We do not yet know what effect it will have on storage piles if beets are allowed to lie in the field after topping as compared to loading direct into trucks. Further research is needed here. This part of our problem is probably nearer to ultimate solution than is the mechanization of Spring work, but they go hand in hand in the final solution.

Beets in storage piles will probably give more trouble as mechanical harvesting is increased. Spoilage losses, where beets are stored over long periods, may become too great for the industry to bear. Important fundamental research on lengthy beet storage is now going on and basic principles must be established.

California factories should benefit from this research also, especially if ways could be found permitting beet storage enough to carry the factories through rainy seasons. Further research and full-scale experiments are now necessary. If this problem is solved the saving to the industry in avoiding shrinkage losses and deterioration in sugar will be tremendous.

The plant breeders still have plenty of problems. As stated above, the necessity for single-germ seed, improved crown type, improvement in sugar content and purity are vital. In addition to that there is much work that can be done in further improving varieties which are resistant or immune to the various diseases, such as seedling diseases, which confront the grower. This is a never-ending fight. Tremendous progress has been made and with the additional skill that scientists are developing further improvement is bound to come and, I believe, very quickly.

One of the major problems confronting both the scientists and the field staffs of the various sugar companies is the improvement of yields. This is going to involve further studies of soils, fertilizers, beet population, rotation practices, which may involve the plowing under of green cover crops, utilization of manure, irrigation practices, and drainage problems. Many other factors will become evident as further study is made.

In summarizing, we know much progress has been made in the past 10 years. However, before the growing of sugar beets is competitive with offshore producers with their low wages, we must do away with the use of large movements of migratory labor. The soil must be treated properly. Plant food must be returned to the land. Preparation, seeding, thinning, and harvesting must be done mechanically. Better use of the beet tops must be worked out and put into practice. Beet yields must be increased. Better beet types will be developed. More will be learned about irrigation and drainage.

The members of the Society will play the major role in the consummation of these problems. Those who are here 10 years from now will look back and see these problems solved. Others will, in the meantime, develop. We all know we are living in a world where new problems loom up daily. With vigorous leadership and interchange of ideas this group can solve the problems as they come up. There is a very necessary place for this Society and I am sure it will live up to its place in the scientific world.

Some Soil Management Practices That Pay

B. T. SHAW[1]

A subject as broad as this one allows considerable latitude in discussion. I used the words "some practices" so that I would be under no obligation to discuss everything. I can discuss what I want to. This being so, I will limit the discussion to the western irrigated region, and will emphasize practices that are important in growing sugar beets.

It is not necessary to tell those of you who have herded a stream of water over a farm that irrigation farming is different. Yet it is necessary to discuss some of these differences so that we may have a full appreciation of the problems of soil management under irrigation and be able to capitalize on the experience gained in other regions as well as in our own. Supplementing rainfall with irrigation water adds certain complexities to farming, yet many basic principles of soil management have universal application.

In undertaking the utilization of the arid lands of the western United States through irrigation, conditions and problems have been encountered that are new to our race. Our agricultural people have been since the beginning of civilization accustomed to farming under rainfall. The engineers who have planned and built our irrigation works have had to meet and solve many new problems, not only in connection with the construction work but more particularly in the continued profitable use of water in agriculture. Irrigation farming may be older than any other kind of highly developed agriculture, but the people of northern Europe who have contributed so largely to our population and occupied our agricultural lands have had no practical experience with irrigation. The engineers who constructed and operated the extensive irrigation works of antiquity in western Asia and northern Africa have left few written accounts of their work, and the problems and difficulties of the men who farmed those irrigated lands have not been recorded. There are evidences that irrigation was used both in North America and in South America long before the arrival of Columbus. In Peru and along the Gila and the Santa Cruz in Arizona the discoverers found irrigation in use to a limited extent, and it is now known that there were much more extensive irrigated areas that had long since been abandoned, as for example the Salt River Valley of Arizona.

There have been a number of instances both in this country and in the Old World where the productivity of irrigated land has been

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comparatively short-lived. In some of these the causes have been obvious; in others, obscure. There appears to be no valid basis for the view sometimes advanced that irrigation farming cannot be continued indefinitely on the same land. Nor is there much foundation for the belief that irrigated lands are made increasingly productive by the salts carried in the irrigation waters.

It is an outstanding characteristic of our arid lands susceptible of irrigation that within a restricted area they are more variable in character and in potential productivity than the lands of humid regions. This fact is due to the nature of their origin and formation. For the most part these irrigable lands have been made along river channels or delta cones. The soil deposited by flood waters may vary from gravel to clay within a few feet, either laterally or vertically. Even where the surface topography is uniform the surface soil may vary in texture and depth between wide limits. The farmer who says, "My soil is different," is usually right.

Added to this initial variability in soils is the complication that these soils developed under scanty rainfall and sparse vegetation. When a farmer starts out with a soil that has developed under perhaps 10 inches of rainfall and then adds possibly 24 to 48 inches of irrigation water a year, which results in much greater production of vegetation, he violently interrupts all of nature's processes and starts a whole new sequence in soil development. His soil was not only different to begin with, but he farms a different soil each year.

If irrigation water were as pure as rain, marked changes would occur in soils as a result of this change in soil climate. But irrigation water is not as pure as rain.

Mark Twain has recorded the observation that you cannot tell by the looks of a frog how far he can jump; an equally vivid observation is that you cannot tell by the looks of irrigation water how much salt it contains. It is a fact that all our underground and stream waters used for irrigation contains salts in solution. The quantity may be small, but they are always present. Furthermore, there are many different salts in these waters, some of which are beneficial to crops, some harmless, and others injurious. The variable quality of irrigation water used in different areas combined with the variability in soils introduces many complexities into the problem of achieving sustained production through soil management.

As a business enterprise irrigation rests on the tacit assumption that it will continue to be effective and will produce undiminished crops for generations to come. Unless that assumption is valid, the whole of the vast financial and social structure of irrigated agriculture must crumble. Considering all the evidence, we must admit that in many districts crop yields are decreasing—and this not because of

less careful or less expert farming but because of obscure factors that lie beyond the farmer's work. Weather, plant pests, and similar crop hazards are not to blame, but on the contrary the formerly satisfactory system of farming itself seems to be at fault. Fortunately, we now know some of the reasons for these declines in yields and have demonstrated in the field ways to prevent them.

Our irrigated lands occur as compact, sharply defined areas, isolated from each other and widely scattered over the western United States. Each has its peculiar combination of climate, soil, and water supply. Each has its own problems and possibilities of crop production and markets for its products. It is very exceptional that the lessons of experience acquired in one of these irrigated regions can be applied with the same success in another. Yet, as I see it, there are five well-paying practices that have general application.

It pays to adjust irrigation methods to soil, water, and crop

In the early days of irrigation in this country it was not uncommon for farmers to use excessive quantities of water. Where the land was rough and water was abundant it was easier to use large heads to cover the land than to level the land and economize with the water. Such wasteful methods of irrigation have largely been abandoned. The evils resulting from them were too obvious to escape attention and are too well known to need elaboration here. The reaction from the earlier excessive use of water has been stimulated by much well-intended propaganda. The irrigator has been urged to use water sparingly, not only in order to permit the fullest utilization of our limited supplies but also for reasons of more direct self-interest. It has been alleged that the liberal use of water not only leaches the fertility from the soil but also that it contributes directly to water-logging the subsoil and thus necessitates artificial drainage which would not be necessary if water were used more sparingly. The ideal system of irrigation as portrayed by some enthusiasts is one in which only enough water is used to supply crop needs in addition to the unavoidable losses by direct evaporation from the soil.

Such rigid economy of water might be practicable if irrigation water were as pure as rain-water. But in view of the fact that irrigation water always contains salts and frequently contains large quantities, it is clearly a short-sighted policy to use so little water that the root zone is never leached.

It is probably not worthwhile to occupy your time with a detailed discussion of the kinds of salt that occur in irrigation water. There are many elements involved, and these may exist in a great variety of combinations. Our interest centers in the effect produced, either on the plants directly or on the physical conditions of the soil which in turn affect the plants. It does not appear from what we now

know that our ordinary crop plants are much more sensitive to one combination of the more common salts than to another. If the soil solution is sufficiently dilute so that the plants can obtain the water they need, they are not much influenced by the character of the salts present. The essential thing is that the plants shall be able to take up the water fast enough to meet the requirements of transpiration and growth. The process of water absorption is interfered with when the concentration of the soil solution is high, almost without regard to the character of the salts in the solution. The point that is emphasized here is that in general the injurious effect of salts in the soil solution occurs by retarding the absorption of water by the plant roots rather than by any poisoning action within the plant. This distinction is important because it indicates how such injurious effects may be prevented.

When we recognize the fact that the soil solution must be kept dilute if our crop plants are to thrive, the way is open to prevent salt injury in irrigation. The salt that accumulates in the soil solution of the root zone is largely brought in by the irrigation water. The only known way to prevent that accumulation of salt is to leach the root zone from time to time and thus carry the salt away. An occasional leaching of the root zones appears to be essential to successful irrigation farming. Unless this is done it is inevitable that in time the soil solution will become so concentrated with salt that the crop plants will be unable to obtain from it the water they need for normal growth.

It will be obvious that if the root zone is to be leached in order to reestablish a dilute solution by removing the accumulated salt, a way must be provided for the leaching water to escape. There are some areas of irrigated land so situated as to have adequate natural subsoil drainage. In general, however, it is found necessary to construct a system of artificial drains. In fact it is coming to be generally recognized that an adequate drainage system is essential to a tract of irrigated land.

In order to prevent the injurious accumulation of salt in the root zone of the soil, the method of irrigation should be such as to insure some leaching of the soil, at least occasionally. The frequency of leaching should be influenced by the quantity of salt in the irrigation water; if the quantity is large, the leachings should be more frequent. In other words the more salt there is in irrigation water the more copiously that water should be applied. I do not share the view that the need of drainage can be avoided by the economical use of irrigation water.

The point I wish to emphasize is this: The accumulation of salt in the soil solution of the root zones is one of the serious hazards in irrigation farming. It is preventable by the provision of adequate drainage and by following a method of irrigation that will insure

effective soil leaching. We cannot avoid irrigation water that contains salt; but it is possible to operate an irrigation system in such a way that the injurious salts will be carried away by the drainage as rapidly as they are brought in by the irrigation water.

It Pays to Grow a Good Crop Rotation

Under proper management and where the soil, water, and climatic conditions are not unfavorable, the yield of the various crops produced under irrigation should be superior to those harvested where such conditions do not exist. But in eliminating the hazards of drought, which has long been recognized as an important limiting factor in securing large crop yields, and in taking advantage of an assured water supply, farmers assumed other responsibilities in connection with their operations which if not adequately met still endanger their success. A substantial proportion of the costs of crop production under irrigation are in the form of fixed charges which must be met regardless of the yield of the crop or even if there is a total crop failure. Thus, while the possibilities of securing larger per-acre returns are greater where the hazards of drought have been eliminated, the financial risks are correspondingly increased if the productivity of the soil is not so maintained that superior yields are assured.

Farmers producing crops under such conditions and confronted with increased operating costs are forced into a more intensive system of farming, because mediocre yields will not cover production costs and fixed charges. Such measures as summer fallowing, often resorted to advantageously in adjoining dry-land areas, are not practical. Because of the intensive cropping of the lands, which is an essential feature to success, unless a constructive farm program is practiced the productivity of the lands becomes more rapidly depleted and the ultimate consequences are more serious to the operators than is the case where the required standard of production is materially less. It is evident, therefore, that a successful agriculture under irrigated conditions is predicated upon the adoption of such a program of farm management that crop yields may be large enough to insure returns in excess of the fixed charges and other costs incident to their production. To attain this objective, a well-planned crop rotation program is now known to be an essential prerequisite.

I hold no brief that crop rotation by itself is the answer to the problem of sustained production. But I do strongly contend that crop rotation provides a most effective mechanism for the functioning of soil management leading to sustained production. In what follows I shall try to show you why I hold this opinion, and further what it is about a crop rotation that makes it either good or bad so far as its effect on the soil is concerned. I am not going to discuss the

other values claimed for crop rotation, particularly as against continuous cropping, such as distribution of risks through diversification, more efficient use of labor, and reduced damage from weeds, insect, and crop diseases. We shall concern ourselves only with the effects of crop rotation upon productivity of the soil.

A high-quality sod-type legume, such as alfalfa, grown alone or in mixtures with clover and grass is of predominant importance in the crop rotation for the irrigated farm. To put soil in condition to grow such a crop successfully should be the initial objective of any soil improvement program.

I do not mean to imply that alfalfa has all good effects. No crop has all good or all bad effects on soil. All crops remove minerals from the soil unless the whole crop is plowed under. Actually, a good crop of alfalfa will remove more of all the mineral elements than correspondingly good crops of sugar beets, potatoes, or corn. But this does not mean we should quit growing alfalfa. It means, simply, that we are likely to have to add minerals to a cropping system containing alfalfa sooner than to one without it. This is well brought out in data from our Huntley, Mont., Field Station. During the second 6-year period following the establishment of the crop rotation experiments, beets grown continuously without treatment produced yields of 9 tons per acre, beets grown in 2- and 3-year rotations without alfalfa gave average yields of 10.5 tons per acre, beets grown in 4-year rotations with 2 years of alfalfa averaged 11.7 tons per acre, and where an additional year of alfalfa was added in a 6-year rotation beets averaged 13.5 tons per acre. During the fourth 6-year period the yields of beets were, respectively, 7.7, 6.7, 5.1, and 9.8 tons per acre. This represents a drop in yield per acre of 1.3 tons under continuous cropping, 3.8 tons in 2- and 3-year rotations without alfalfa, 6.6 tons in 4-year rotations with 2 years of alfalfa, and 3.7 tons in 6-year rotations with 3 years of alfalfa. By way of comparison, beets grown in a 6-year rotation with 3 years of alfalfa but receiving manure also, produced yields of 16.7 tons per acre for this same fourth 6-year period.

In the second 6 years of this experiment soil nutrients were still at a high enough level to permit alfalfa without treatment to exert a beneficial effect on yields of beets. In the fourth 6-year period the level of nutrients was too low for alfalfa to function. These data do not condemn alfalfa, but on the contrary they emphasize the fact that machinery run at a faster rate requires more fuel. Both irrigation and alfalfa permit farming at a faster rate and if we are to take advantage of these potentialities we must adjust other management practices in line with the speed we wish to travel.

In an experiment at Huntley where alfalfa, manure, and fertilizers exert a combined influence on beet yields, the average produc-

tion for the last 19 years has been 20.5 tons per acre. I could cite other data from both the humid and irrigated regions to show the beneficial effects of rotations over continuous cropping and of rotations with legumes over rotations without them, but I believe most of you are already familiar with these data. The evidence I have examined indicates a marked tendency for yields to decline when cultivated crops like corn, sugar beets, and potatoes are grown continuously, and a somewhat slower decline, although still notable, when the same crops are grown in rotation, unless the rotation includes a sod legume like clover or alfalfa.

I believe the most important reason that crop rotation including sod legumes is such a vital factor in maintaining soil fertility is that in such systems soil organic matter may be maintained. Where clean-cultivated crops are grown exclusively this is next to impossible by economic methods.

The explanation for these widely different effects of crops upon soil organic matter and nitrogen, I believe, lies in two important factors: (1) the amount of soil tillage required in growing the crop, and (2) the amount and composition of the root and stubble residues left by the crop. Organic matter is destroyed through the activity of bacteria and other microorganisms in the soil. The process is essentially one of oxidation and requires air, just like oxidation through combustion. Each time the soil is stirred, air is introduced into the soil and the rate of organic decomposition is speeded up. This probably explains why the destruction goes on so fast under corn and other intertilled crops. With the small grains the only tillage necessary is that given in preparing the seedbed, and with the hay crops as commonly grown no additional tillage is required beyond that given in preparing for the seeding of the companion crop.

Now let us turn to the matter of crop residues which determine how much accumulation of organic matter takes place. Before commenting on the individual crops it should be pointed out that the amount of humus left in the soil from the incorporation of equal weights of different kinds of residues varies considerably. Without taking time to explain why, it may be said that residues whose nitrogen content is low, such as those from corn and small-grain crops, disappear much more completely and leave relatively small amounts of humus compared to nitrogen-rich residues, such as those from alfalfa and sweet clover. For example in one experiment at Ohio State University equal weights of a number of different crop residues were incorporated with the soil. One of these was corn stover, low in nitrogen, another sweet clover, high in nitrogen. At the end of 1 year of active decomposition the amount of humus left was in the case of corn

stover only 17 percent of the weight of the stover added, whereas it was equal to 50 percent of the amount added in the case of sweet clover.

Here it might be interesting to cite a few figures showing the amounts of roots and nitrogen left in the soil after harvesting a few of the common crops as determined in some Ohio experiments.

Corn, 60-bushel yield. 800 pounds roots, 10 pounds nitrogen.

Soybean, 19-bushel yield, 550 pounds roots, 9 pounds nitrogen.

Red clover, 1.5 tons, 1,000 pounds roots, 22 pounds nitrogen.

Alfalfa, 3 tons yield, 3,900 pounds roots, 90 pounds nitrogen.

Alfalfa clover, at end of seeding year, 2,600 pounds roots, 96 pounds nitrogen.

From these figures it is easy to see why sod legumes are so effective in maintaining soil organic matter and nitrogen compared to such crops as corn and soybeans. Right along this line, it is interesting to point out that from soil studies made on some of the old fertility experiments in Ohio it was found that stable manure was twice as effective in maintaining soil organic matter and nitrogen when applied to a crop rotation including clover as it was when applied to continuous corn. Even chemical fertilizers carrying no organic matter have increased the amount of soil organic matter when applied to the small grain with which the clover was seeded. Apparently anything we do to a soil that results in better growth of the sod lgeumes is effective in keeping up the content of humus and nitrogen in the soil.

Now I want to point to some further advantages of sod legumes or legume-grass mixtures in the crop rotation. All farmers know what we mean by good soil tilth—that mellow, granular condition so favorable to the growth of most crops. We have in Ohio some very heavy clay soils where the maintenance of good physical conditions seems to be more important in obtaining high yields than supplying plant nutrients, with which these soils are naturally well supplied. When originally cleared these soils were fairly easy to drain and handle and they produced high yields. Forty to fifty years of cropping, chiefly to corn and oats, has left them seemingly much heavier, needing additional drainage, much more difficult to cultivate, and producing much lower crop yields. Laboratory studies show that they have lost their original granular structure, contain much less pore space and are more impermeable to both air and water. In recent years it has been discovered that the best way to get these soils back into a healthy state is to introduce sod crops in the rotation. It appears that the fine fibrous roots of the legumes and grasses are peculiarly efficient in rebuilding these soils into a granular condition, while at the

same time the deep-rooted legumes bore down through the heavy subsoil and leave channels through which water and air can move down to the tile lines.

I believe that next to keeping the root zone free of excess quantities of injurious salts, the kind of crop rotation followed is the most important factor in determining the trend in soil fertility on almost any irrigated farm.

It pays to take good care of manure and to apply it intelligently

The benefits of using farm manure in sugar beet production are too well-known and too well-appreciated to require much elaboration. Growing sugar beets without manure is like leaving the whiskey out of a highball. The kick just is not there.

The liquid is the most valuable part of manure. Plenty of bedding and tight floors in stables and manure pits diminish its loss. Heating losses of nitrogen and organic matter are best prevented by keeping the manure moist and well tramped. The most valuable part of the nitrogen is lost when the manure heats, dries out, or freezes. Such loss may take place after spreading on the field. Immediate plowing under after spreading is the only feasible method of prevention. It is impractical to prevent considerable loss of nitrogen from manure produced in warmer months. Such manure is best used by top-dressing new meadow seedings or established alfalfa after the last cutting. Manure produced late in fall and in winter is best kept under good storage conditions and applied just before plowing for spring crops.

The value of a ton of manure in terms of increased yields in five rotation comparisons at our Scottsbluff Field Station ranged from $2.32 to $4.62 per ton, with an average value of $3.57 per ton for a 25-year period.

It pays to use chemical fertilizer generously

It seems to me that if there is one prejudice among western farmers it has to do with the use of commercial fertilizers. They have long boasted of their fertile soils and too many still believe that it is a reflection on their farming if they have to use fertilizers to maintain yields. This prejudice is gradually breaking down as is evidenced by the rapid increases in fertilizer consumption during recent years. The country as a whole used 7.4 percent more plant food in 1944 than in 1943, but in the western region the increase was 30.6 percent. When compared with the 5-year (1935-39) average, usage in 1944 was 243 percent of pre-war in the western region. This is marked progress, but I believe you have only begun to exploit the possibilities of using fertilizers in crop production under irrigation.

At the Utah Station in fertilizer tests over the last 12-year period, yields of sugar beets were increased an average of 42 percent

by the addition of treble superphosphate, 72 percent by the addition of farm manure, and 83 percent by the addition of both manure and treble superphosphate. In other tests treble superphosphate increased alfalfa yields 2.69 tons over the check plots, where the average yield was 2.76 tons per acre. As an average of 4 years' results, peach trees yields 308, 478, and 509 bushels per acre with no fertilizer, 3 pounds ammonium sulphate per tree, and 3 pounds each of ammonium sulphate and treble superphosphate per tree, respectively. This is an increase in production of more than 60 percent from nitrogen and phosphorus. At the Idaho Branch Station at Aberdeen, returns per dollar invested in phosphate applied to alfalfa averaged $7.73 for rates of treble superphosphate from 75 to 250 pounds per acre in 3 years, and $4.36 for rates from 300 to 900 pounds for acre in 3 years. When the increased yields of potatoes following the alfalfa were also considered, the returns per dollar invested in phosphate were $11.34 and $10.90, respectively.

I could cite more examples of profitable use of fertilizers under irrigation, but the point I want to emphasize is this: Under irrigation you have eliminated the hazard of drought and in so doing you have made possible a level of production far above that in our humid regions. To attain this level of potential production requires that other factors that may limit production also be eliminated. If the potential production is reached, plant nutrients will be removed from the soil at a more rapid rate than under humid agriculture. Thus, after an initial period of farming under irrigation, it will be necessary to apply larger quantities of fertilizer if yields are held at the high levels that are possible.

There is no argument of farm manure *versus* fertilizer. Use manure. Use all you have. But you do not have enough. And even where you have manure it often needs supplementing with either nitrogen or phosphorus and frequently both, if best results are to be obtained.

I should like to point out that intelligent use of fertilizers will require that other management practices be adjusted in keeping with the increase in plant nutrients. With higher levels of fertility we will want more plants per acre and we will use more water than was used in growing half of the potential crop.

It pays to follow a complete program of soil management

Highest efficiency in crop production is attained only when all elements of good soil management are used in combination and followed consistently. One-sided sporadic attempts at soil management are only partially effective. Crop yields in the West could probably be increased 50 percent or more by the adoption of well-proved methods of soil management.

GENERAL AGRONOMY

Comparison of the Effects of Manures and Commercial Fertilizers on the Yield of Sugar Beets[1]

ROBERT GARDNER and D. W. ROBERTSON[2]

Manures and commercial fertilizers are recognized as good sources of plant nutrients. Manures, however, contribute many things to the soil which are not contained in commercial fertilizers. The two classes of materials are therefore not wholly comparable, but some comparisons are useful as an indication of the extent to which commercial fertilizers can be substituted for manures. The results of such comparisons are now being obtained in an experimental program on the Agronomy Farm of the Colorado Agricultural Experiment Station.

The following report covers the effects of manures and commercial fertilizers on two crops of sugar beets in an experiment designed to continue through an 8-year rotation. The rotation has not yet been completed but the effects of the treatments on the yields of the two crops of sugar beets are believed to be of sufficient interest to justify reporting them before completion of the experiment.

The sequence of the crops in the rotation is as follows: Sugar beets, small grain, sugar beets, alfalfa (4 years), and corn. The experiment began with sugar beets which were preceded by corn. The corn followed alfalfa. The soil is Fort Collins loam and is naturally very fertile, but it had not received any manure in more than 10 years when the experiment was started. However, the land had been in a previous fertilizer experiment beginning in 1935. The previous fertilizer treatments consisted primarily of varying rates of nitrogen application but several phosphate treatments were also applied. The effects of some very heavy phosphate applications were still evident in 1941 but no evident effects of the nitrogen treatments remained. The previous experiment was reported in an earlier paper (*1*)[3].

Because of the previous experiment on the land it was necessary to retain the original plot arrangement which consisted of 4 blocks of 21 plots each. It was also necessary to arrange systematically the treatments superimposed on the previous phosphate-treatment plots.

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[1]Paper number 209, Scientific Journal Series, Colorado Agricultural Experiment Station.

[2]Agronomists, Colorado Agricultural Experiment Station, Fort Collins, Colo.

[3]Italic numbers in parentheses refer to literature cited.

Table 1.—Soil treatments.

No.	Manure (5 tons/acre) Kind	Manure (5 tons/acre) Date	Treble superphosphate Rate/acre	Treble superphosphate Date	Ammonium sulphate Rate/acre	Ammonium sulphate Date	Potassium sulphate Rate/acre	Potassium sulphate Date	Sodium sulphate Rate/acre	Sodium sulphate Date
1	(check)								99 pounds	April 1942
2										
3			5,000 pounds	June 1935						
4			5,000 pounds	June 1935	(649 pounds (165 pounds	April 1942 April 1944				
5			5,000 pounds	June 1935	(649 pounds (165 pounds	April 1942 April 1944	(314 pounds (223 pounds	April 1942 April 1944		
6			(150 pounds (116 pounds	April 1942 April 1944	(649 pounds (728 pounds	April 1942 April 1944				
7			(150 pounds (116 pounds	April 1942 April 1944	(649 pounds (728 pounds	April 1942 April 1944	(314 pounds)349 pounds	April 1942 April 1944		
8					(649 pounds (728 pounds	April 1942 April 1944				
9	Old	Oct. 27, 1941								
10	Old	Oct. 15, 1941								
11	Old	Oct. 15, 1941			60 pounds	April 1942				
12	Artificial	Oct. 27, 1941								
13	Old	April 10, 1942								
14	Old	March 27, 1942								
15	Fresh	April 10, 1942								
16	Fresh	April 11, 1942*								
17	Fresh	March 27, 1942								
18	Fresh	March 27, 1942			113 pounds	April 1942				
19	Artificial	April 10, 1942								
20	Straw	April 10, 1942	636 pounds	April 1942	601 pounds	April 1942				
21	Alfalfa	April 10, 1942								

*Spread on surface after plowing

These included 5 plots in each block. The new treatments were randomized in the other 16 plots of each block. A total of 21 treatments are included. These are outlined in Table 1. All the manure and other organic materials were applied at the rate of 5 tons of dry material per acre. The individual treatments are discussed in connection with the comparisons made in presenting the experimental results shown in table 2.

Table 2.—Effect of fertilizers on beet crop.

Treatment No.		Tons beets		Pct. sucrose		Tons sucrose		Pct. stand	
		1942	1944	1942	1944	1942	1944	1942	1944
1	(check)	11.42	11.21	15.3	18.3	1.75	2.05	90.6	69.9
2	(S)	13.02	12.55	15.5	18.8	2.02	2.36	92.6	79.5
3	(P)	14.86	15.32	15.5	19.0	2.30	2.91	98.9	81.4
4	(NP)	18.24	17.48	15.3	18.9	2.79	3.30	97.4	85.5
5	(NPK)	18.19	16.31	15.2	18.8	2.76	3.07	92.4	84.9
6	(NP)	17.44	17.31	15.2	18.2	2.65	3.15	95.4	85.1
7	(NPK)	17.05	16.68	15.5	18.2	2.64	3.04	98.3	86.0
8	(N)	14.90	12.74	15.4	18.1	2.29	2.31	94.8	81.4
9	(Old manure)	15.68	14.21	15.9	18.7	2.49	2.66	96.1	86.9
10	(Old manure)	15.43	14.37	15.7	18.9	2.42	2.72	94.4	75.4
11	(Old manure)	15.76	15.33	15.8	19.2	2.49	2.94	100.5	89.5
12	(Art. manure)	13.61	14.35	15.9	19.1	2.16	2.74	96.8	86.1
13	(Old manure)	15.56	14.59	15.6	19.0	2.43	2.77	96.8	81.1
14	(Old manure)	15.62	15.18	15.7	19.1	2.45	2.90	98.3	84.5
15	(Fresh manure)	17.62	14.34	15.3	18.3	2.70	2.62	93.9	84.1
16	(Fresh manure)	15.65	14.19	15.8	18.6	2.47	2.64	100.5	84.5
17	(Fresh manure)	16.45	15.46	15.2	18.6	2.50	2.88	92.8	74.5
18	(Fresh manure)	17.58	16.28	15.3	19.0	2.69	3.09	96.8	89.9
19	(Art. manure)	13.93	12.33	15.7	18.8	2.19	2.32	92.5	92.5
20	(Straw + NPK)	16.03	18.06	15.1	18.7	2.42	3.38	90.5	88.2
21	(Alfalfa)	18.08	16.04	15.2	19.2	2.75	3.08	97.8	80.4
		332.12	314.33	325.1	393.5	51.36	58.93	1008.1	1741.3
	Mean	15.82	14.97	15.58	18.74	2.446	2.806	95.62	82.91
	(S. E. of diff.) x 2	1.72	2.69	.441	.508	.290	.510		

Experimental Results

Effect of the Nitrogen, Phosphorus, and Potassium Balance on Crop Yields.—The treatments numbered 3, 4, 5, 6, 7, and 8 in Tables 1 and 2 are commercial fertilizer treatments. These may be compared with each other and with the manures numbered 9 to 21. Numbers 3, 4, and 5 had previously received very heavy phosphate applications, 6 and 7 light applications, and 8 no phosphate. The fertilizers put on in 1942 were applied at rates for each constituent equal to the soluble amount of that constituent in the fresh manure applications. Treatment 2 was added to the experiment as an additional check to determine the possible effects of sulphur in the ammonium sulphate used as the nitrogen carrier.

A comparison of treatments 1 and 3 shows an increased yield of 3.44 tons in 1942 and 4.11 tons in 1944 resulting from the heavy phosphate application in 1935. Comparing treatment 4 and 3 shows that adding nitrogen to the phosphated plots increased the yield 3.38 tons more than the phosphate alone in 1942 and 2.17 tons in 1944. There was no significant difference between the results where nitrogen, phosphorus, and potassium were all three applied in treatment 5 and those where only the two elements were applied in treatment 4. It is evident from these results that potassium was not a limiting factor in the soil.

Numbers 4 and 5 were treated again for the 1944 crop at rates of application comparable to the insoluble constituents in the fresh manure, the purpose being to make the nutrients applied by each fertilizer in the two applications equal in amount to the same elements applied in the manure. It was also desired to see what the effect on the second crop would be of applying fertilizer constituents approximately equal to another application of manure. Applications were therefore made to numbers 6, 7, and 8, in 1944 in amounts approximately equal to the total of each constituent in a manure application of 1942. These heavier applications resulted in a significant reduction of sugar percentage, indicating that the nitrogen was slightly in excess of the needs of the crop. A comparison of the sucrose percentages of treatments 6, 7, and 8 with most of the other treatments shows significantly lower percentages in these treatments.

Comparison of the Effects of Manures and Commercial Fertilizers on the Yields of Beets.—Treatment 7 received the same amount of nitrogen, phosphorus, and potassium as there was in the soluble portion of the manure applied to treatments 15 and 18. The yields are nearly the same. Since treatments 6 and 7 also gave nearly the same yields, the results indicate that the increased yields in this experiment resulting from either the manures or commercial fertilizers can be attributed to the nitrogen and phosphorus in these materials. It is apparent that so far as the sugar beet crops in this experiment are involved commercial fertilizers were able to take the place of manure. Economically, the use of so much fertilizer probably would not be feasible. Additional fertilizers were used on the fertilizer plots in 1944 and the yields were greater than on the manure plots, indicating that the manure added in 1942 was not adequate for the two crops of beets and the grain crop produced in 1943.

Relative Values of Old and Fresh Manures and Fall and Spring Applications.—Well-decomposed manure usually is considered superior to fresh manure. The fresh manure in this experiment, however, produced slightly higher yields than the older material. A comparison of the yields from treatments 13 and 14 with 15, 16, 17, and

18 will show that the yields are slightly better for the latter group which are the fresh manure treatments.

Fresh manure was not available for fall application but comparisons were made of old manure from the same pile applied both in the fall and spring. There is no evident difference in the results.

Application of Manure before plowing and after Plowing.—Treatment 16 was spread on the surface of the soil just after plowing and was disked into the soil. The only difference in treatments 15 and 16 is that manure in 15 was spread on the soil just before plowing and manure in 16 just after. The beets in No. 16 grew much faster early in the season but the yield was 2 tons per acre less in 1942 than on the land where the manure was plowed under. The 1944 yields are practically the same for both treatments.

Decomposed and Undecomposed Artificial Manure and Alfalfa as a Manure.—Treatments 12 and 19 were well decomposed artificial manure made by adding water, ammonium sulphate, finely ground limestone, and treble superphosphate to straw and allowing the mixture to decompose in a pile. The material was analyzed and, on the basis of the analysis, enough ammonium sulphate and treble superphosphate and fresh straw were applied to the soil as treatment 20 to equal the constituents of the artificial manure. The potassium in the straw was slightly higher than in the artificial manure.

A comparison of treatment 20 with treatments 12 and 19 shows that the undecomposed straw supplemented with nutrients equal to the artificial manure produced decidedly better results than the artificial manure. Similar results have previously been observed with artificial manures by Heck (*3*, *4*).

Because of the high plant nutrient content of alfalfa it has sometimes been used as manure and frequently is available in small quantities at stack bottoms. Alfalfa was therefore used in the test. It ranked about equal to the straw and fertilizers over the 2-year period and was slightly superior to the other manures.

Loss of Manure in Storage and from Delayed Plowing after Spreading in the Field.—Manure is known to be a somewhat perishable product and suffers losses both in storage and after spreading in the field. Some observervations on this problem were made in this experiment. The results of this study have already been reported elsewhere (*2*) by the writers. Under the conditions of storage in an open pile, manure from the same lot of fresh manure used in the fertilizer experiment lost more than 50 percent of its nutrients and organic matter in a year. When spread on the soil for 2 weeks before plowing, a loss of a little over 20 percent of the nitrogen occurred.

This latter loss did not affect the yield significantly as is shown by a comparison of treatments 10 and 11 and 18 and 19.

Summary

A field plot experiment now in progress to study the comparative values of manures and commercial fertilizers has given the following results:

1. Phosphorus and nitrogen were both found to be deficient in the soil. Phosphorus added as commercial fertilizer gave approximately 3.5 tons increase in yield of sugar beets. Phosphorus and nitrogen gave approximately 7 tons increase. Addition of potassium to the combination gave no increase over the nitrogen and phosphorus.

2. Nitrogen and phosphorus fertilizers applied at a rate to give the same amount of these elements as there was in the soluble portion of an application of manure gave increase in sugar beet yields equal to that resulting from the manure.

3. Fresh manure was slightly superior to well-decomposed old manure.

4. Application of manure to the land after plowing gave slightly better early growth but lower final yield of beets than manure plowed under.

5. Fresh straw with enough nitrogen and phosphorus added to equal the nitrogen and phosphorus in well-decomposed artificial manure made from straw and commercial fertilizer gave much better results than the artificial manure.

6. Manure stored in a pile for a year lost more than 50 percent of its nutrients and organic matter.

Manure spread on the surface of the soil 2 weeks before plowing lost 20 percent of its nitrogen but did not cause a significantly lower yield of beets than manure plowed under immediately after spreading.

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Restoring Fertility to Land Where Levelling Operations Have Removed All the Top Soil and Left Raw Subsoil Exposed

D. W. Robertson and Robert Gardner[1]

In the past few years with the advent of suitable power machinery, considerable levelling of irrigated land has been undertaken. Much of this levelling removes all of the surface soil and, in some cases penetrates deeply into the subsoil in the areas "cut" and may leave this subsoil on top in the areas of "fill". The object of this levelling process is to increase the efficiency and distribution of irrigation water.

Previous work (*1*)[2] has shown that a high percentage of our subsoils are deficient in available phosphate and nitrogen. This brings up the question of what is the easiest and most economical way of raising the yielding ability of the soils exposed by levelling to somewhere near that of the original surface soil.

In the spring of 1945 on a block of land on the Experiment Station Farm, levelling was done by the Soil Conservation Service. In part of this area the surface soil and some of the subsoil was removed, leaving the subsoil exposed. The soil was transported to other parts of the field not included in the experimental area. On this area a fertility experiment was laid out and seeded to alfalfa with a companion crop of Colsses barley. The range in depth of "cut" was from 1.2 feet in plot 6 to 0.2 foot in part of plot 24. With the exception of this latter depth, all the "cut" area used for plots had 0.5 foot or more of the surface removed. The soil treatments were as follows: No treatment, manure, manure plus 125 pounds of treble superphosphate (43 percent P_2O_5), manure plus 500 pounds treble superphosphate, manure plus 1000 pounds treble superphosphate, and manure plus 125 pounds treble superphosphate and 125 pounds potassium sulphate (40 percent K_2O).

The heavy applications were used because previous experiments (*2*) had shown that heavy applications of treble superphosphate on the Station soil (Fort Collins loam) showed a residual effect on beets after the complete cycle of an 8-year rotation. All the experimental area with the exception of the no-treatment plots was manured at the

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[2]Italic numbers in parentheses refer to literature cited.

rate of 10 loads of feed-lot manure from the cattle feeding pens after the land was levelled. After the land was manured it was plowed, packed, harrowed, and floated. After this treatment, commercial fertilizer was applied, as outlined, with a grain drill having a fertilizer attachment. The plots were then harrowed and drilled to alfalfa and barley. One irrigation was applied during the growing season and one to the alfalfa after the grain had been threshed. Because of unfavorable weather the lateness of starting the levelling process, seeding was delayed until May 2.

During the entire season the effect of the treatments could be easily seen. Table 1 gives the grain and total yields and the bushel weights obtained with the different treatments. While the yields on the treated plots were low, they were in line with similar yields on adjacent plots which were planted about the same date (table 2).

Table 1.—Fertility treatments to increase yields on land levelled to remove surface soil.

Series 4600	Planted May 2		Emerged May 12		
	1945				
	Yield per plot in pounds		Yield per acre in pounds		Test weight
Treatment No.	Grain	Total	Grain	Total	Pounds
No	29.75	46.25	405	629	40.25
Manure—10 loads per acre	64.625	113.0	879	1,537	42.25
Manure+125 pounds phosphate	82.0	144.25	1,115	1,962	43.15
Manure+500 pounds phosphate	74.375	142.25	1,012	1,935	43.425
Manure+1000 pounds phosphate	89.25	171.25	1,214	2,329	43.3
Manure+125 pounds phosphate 125 pounds potassium sulphate	88.375	171.75	1,202	2,336	42.75
Mean yield			971	1,788	
Difference to be significant			181	535	

Table 2.—Date of planting Spring barley on fallow, 1945.

Variety	Date planted	Date emerged	Date ripe	Yield	
				Bushels per acre	Pounds per acre
Thebi	3-21	4-9	7-27	24.6	1,181
Lico	3-21	4-9	7-28	73.8	3,542
Trebi	3-31	4-23	7-27	56.5	2,712
Lico	3-31	4-23	7-31	71.6	3,442
Trebi	4-9	4-30	7-29	69.4	3,331
Lico	4-9	4-30	8-1	80.4	3,859
Trebi	4-30	5-9	8-2	54.5	2,616*
Lico	4-30	5-9	8-3	46.6	2,237*
Trebi	5-11	5-24	8-7	35.5	1,694*
Lico	5-11	5-24	8-7	48.8	2,342*
Trebi	5-19	5-29	8-16	14.5	696
Lico	5-19	5-29	8-16	23.6	1,133

*Comparative dates.

The analysis of variance indicates there is a significent difference in yield. The application of manure increased the yield from 405 pounds grain to 879 pounds grain or 117 percent. The quality of the grain as indicated by the test weight also shows an improvement for the application of manure and fertilizer. Little difference is shown between the different plots receiving fertilizer in addition to manure. The carry-over effect of the heavy applications will be determined on the succeeding crops of the 8-year rotation: Alfalfa, alfalfa, alfalfa, corn, beets, wheat, beets, and barley seeded to alfalfa.

Chemical analyses of the plant material from the experiment showed a large and significant increase in the soluble phosphate content of the fertilized green plants when compared with the untreated plants. The increase in phosphate was accompanied by a significant decrease in potassium and an apparent decrease in soluble nitrogen, though the nitrogen decrease was not significant.

There were slight and not significant differences between the total phosphorus and total nitrogen of the fertilized mature grain when compared with the unfertilized grain. There was, however, a significant difference in kernel weights.

Table 3.—Chemical analyses of green plants and mature grain.

Treatment	Soluble P in green plants (6/25/45)	Soluble K in green plants (6/25/45)	Soluble N in green plants (6/25/45)	Total P_2O_5 in grain	Total N in grain
	ppm	p/10,000	ppm	Pct.	Pct.
1 No fertilizer	125	110	500	.76	2.04
2 Manure (10 loads)	225*	110	305	.87	1.88
3 Manure+125 pounds phosphate	200*	97*	335	.81	1.73
4 Manure+500 pounds phosphate	301*	99*	265	.84	1.86
5 Manure+1000 pounds phosphate	305*	94*	355	.79	2.02
6 Manure+125 pounds phosphate + 125 pounds potassium suphate	176	95*	290	.78	2.03
S. E.	48.7	7.3	22.9	.075	.121
Difference for significance	69.5	10.3	32.3	.102	.172

*Significant by 5 percent point from no treatment (No. 1)

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Liquid Phosphoric Acid as a Fertilizer

R. A. Jones and Jesse Green[1]

Because of the slight movement of phosphorus from solid phosphate fertilizers in the soil there has been a search for some compound of phosphorus or some method by which this element could be made to penetrate the soil and be more accessible to plants. In the fertilization of citrus trees in the Southwest the need for greater penetration is especially important, and phosphoric acid in the irrigation water has solved the problem of getting the fertilizer to the roots of the trees.

Following the success with phosphoric acid on trees the practice is now used for all other crops, especially the deep-rooted crops such as sugar beets and alfalfa.

Method of Application

Liquid phosphoric acid containing 54 percent P_2O_5 is produced commercially. It is shipped in tank cars and distributed in smaller lots in iron drums. The acid is run from the drums into irrigation water at the head of the lands to be irrigated and fertilized. The rate of flow of acid is regulated so as to deliver a given number of pounds to the water as it is covering a given number of acres. No particular difficulty is experienced in getting the distribution of a specified amount of P_2O_5 per acre on the land.

The acid must, of course, be added to the irrigation water some little distance above where it is diverted into the various rows or lands so as to get uniform mixing. This is best accomplished by placing the drums containing the acid on a bridge or on timbers laid across the ditch so as to deliver the acid near the center of the irrigation stream. It is advantageous to have the mixture of water and acid turn at least one sharp bend in the ditch to insure good mixing.

At the present time phosphoric acid is applied at the rate of 100 to 200 pounds per acre. In all probability this rate will be increased in the future, or more than one application will be made on a crop.

Advantages

The advantages of the method are better penetration, better dispersion of plant food, conversion of the natural phosphates in the soil to more soluble compounds, saving in labor and equipment in distribution, and exact timing of the application to meet the need of the crop.

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Penetration

Penetration varies according to the type and condition of the soil. In open sandy soils it is obviously much greater than in close-packed, alkaline, clay soils. In most soils the phosphorus is retained in the first foot, but in some cases it is found to penetrate as much as 20 to 30 inches.

Dispersion

Because of better penetration of the liquid fertilizer there is almost complete dispersion of the added phosphorus throughout the root zone. As the very dilute phosphoric acid flows into the soil it is fixed by the bases present. In the past, fixation has been considered a very serious change occurring to phosphate fertilizers, but more recent observations in which we see the effect of one application of phosphate continuing from 2 to 4 years indicates that the losses are not as much as was formerly believed. In fact fixation is a very important provision of nature to prevent losses of the valuable element, phosphorus.

With any form of phosphorus fixation must occur, and we must rely on the plant to give off acid in the form of carbon dioxide from its roots to redissolve the solid phosphates. In the case of liquid fertilizers the dilution is so great that phosphorus may be taken up by the growing plant without going through the solid stage. However, the greater part of the phosphorus used in irrigation water is precipitated in a finely divided state throughout the entire root zone where it will be subject to the action of carbon dioxide from all the roots of the plant, rather than only a few roots as when solid fertilizer is applied.

The practice of feeding crops by side dressing as they need plant food has been widely used with varying success. When solid phosphates are placed near enough to a growing plant to be of value there is usually pruning of new roots. Often this injury offsets any advantage gained by the added plant food. With liquid fertilizer the new material moves in and around the roots with the irrigation water without disturbing the plant at all. Also the new food material is so dilute that no root has to grow through or combat a concentrated zone of fertilizer material as when the material is applied in the solid state with a side dressing tool.

Conversion of Natural Phosphates

When phosphoric acid moves into the soil it is fixed temporarily as described above. This change is brought about by the bases in the soil acting with the phosphoric acid. A portion of these bases are natural phosphates resembling raw rock phosphate which are converted by the acid to more soluble forms of phosphorus. The effect is the same

as that carried out in the production of treble superphosphate in the manufacturing plant where phosphoric acid is added to raw rock phosphate.

Saving in Cost of Application

The saving in cost of application of liquid fertilizers over the application of solid fertilizers is considerable. Irrigation must be carried on in any event, and after the drums are placed over the ditch it is only a small effort to regulate the flow of acid. No drills or expensive equipment are required to apply liquid fertilizer; only a small device to go into the opening of the drums to regulate the flow of acid. This device costs about 25 cents.

Exact Timing of Fertilizer Application

Another outstanding advantage of liquid fertilizer is that it may be applied to a crop at any stage of development. As formerly stated a growing crop can use a portion of the liquid fertilizer at once, and the remainder is placed in a very advantageous position about the roots. Effects of the fertilizer can begin immediately, whereas with solid fertilizers there is delayed action. With some crops, and especially with sugar beets, it is important that the plants have their phosphate early in life. To meet this situation a system known as pre-irrigation is practiced; that is, the land is irrigated and phosphoric acid applied before planting. In some localities pre-irrigation is practical, or in other districts where beets are irrigated up the use of liquid fertilizer will fit into the plan of operation. Phosphoric acid applied early to beets has the best opportunity to aid the crop.

Evidence is accumulating which indicates that seeds germinate better when crops are irrigated up with water containing liquid phosphoric acid. Continued observations are being made on this effect of liquid fertilizer.

In Practice

In the field it has been difficult to get actual comparisons of solid versus liquid phosphates. A serious effort is now being made to get these data. Recently the writers conferred with users of liquid phosphoric acid in the Salinas and Imperial Valleys of California and the Salt River and Yuma Valleys of Arizona. The prevailing opinion is much in favor of liquid phosphoric acid. Its use on crops in these areas has reached well beyond the experimental stage. At present the alfalfa crop represents the greatest acreage fertilized with liquid phosphate.

On beets some measurements of the results of the use of phosphoric acid have been made. On the Isabell-Hartner farm at Phoenix an increase of over 800 pounds of beet seed per acre was produced with an application of 200 pounds of phosphoric acid.

Tests conducted in the Delta region of Utah on alfalfa last season gave outstanding results. Also in Montana comparative tests with phosphoric acid versus treble superphosphate were conducted on potatoes at the Donick ranch at Deerlodge. The phosphoric acid gave an increased yield of 27 sacks per acre as against 13 sacks from the treble superphosphate. With trees the actual results of a given fertilizer must be observed over a long period of time and because there are usually various combinations of fertilizers used it is difficult to evaluate the results. On the Frank Cihak place at El Centro, Calif., a grapefruit orchard produced over 27 tons of fruit following a 3-year treatment with phosphoric acid and other fertilizers. This is said to be one of the highest production records in the district.

Perhaps the best results from the use of phosphoric acid has been on vegetable crops and alfalfa. On the whole, the use of phosphoric acid represents a step forward with fertilizers to increase agricultural production.

Side-Dressing Sugar Beets with Nitrogen in Western Montana

EDWARD L. SWIFT[1]

Beets for the Missoula factory are produced largely in four small mountain valleys at altitudes from 3,000 to 4,000 feet. These valleys are in western Montana and are within 100 to 200 miles of the Canadian border. About 20 percent of the acreage is grown east of the Continental Divide in the Missouri River Valley, and the balance on the western slope in the upper Columbia River Basin.

During recent years definite symptoms of nitrogen deficiency have been observed in many sugar beet fields in the Bitter Root Valley of western Montana. Although there is a considerable amount of livestock feeding, there is never enough manure produced to fertilize all the beet land. It has been standard practice to apply 100 pounds of treble superphosphate (0-43-0) per acre and to broadcast this fertilizer with a grain drill before beet planting.

In 1941 Afanasiev and Morris (*1*)[2] conducted fertilizer experiments in cooperation with several growers in the Bitter Root Valley and from these preliminary tests determined that 20 pounds of nitrogen in the form of ammonium sulphate, either side-dressed or applied before seeding, increased sugar beet yields about 10 percent.

During the 1944 and 1945 crop seasons, field tests were conducted comparing varying amounts of nitrogen applied to 16- to 20-row strips of beets after thinning was completed. The results of these tests and the method of application are herein reported.

1944 Results

Two fields were selected for side-dressing experiments in 1944. One was a sandy loam field of average fertility, unmanured, and the other was a low-fertility field manured at the rate of 10 tons of cattle manure per acre. Each field received 150 pounds of treble superphosphate before planting. The nitrogen was applied in the form of ammonium sulphate between the rows on July 7. Strips as harvested were 12 rows wide and are summarized in table 1.

These tests indicated that there was a great deficiency of nitrogen, particularly in the field which was not manured. Further, evidence was obtained that improved yield and greater profit could be obtained from applying nitrogen in amounts greater than 20 pounds per acre.

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[2]Italic numbers in parentheses refer to literature cited.

Table 1.—Effect of side-dressing of varying amounts of nitrogen on yield and quality of sugar beets, 1944.

Treatment	No manure Average fertility Tons beets per acre	Manured Low fertility Tons beets per acre	Sucrose percentage
82 pounds nitrogen	15.06	13.27	18.7
41 pounds nitrogen	13.59	12.57	18.2
Check, no nitrogen	11.33	11.63	18.7

1945 Tests

In 1945 it was found impossible to purchase side-dressing equipment for use in large-scale tests. Therefore the American Crystal Sugar Company built three machines: A three-row, a four-row, and a six-row machine. The four-wheel tractor was adjusted to straddle three beet rows. With this arrangement it was possible to use six openers and fertilize every center in the six-row plantings. To side-dress every middle with a three-wheel "Farmall" type tractor, it is necessary to straddle an even number of rows and to use an extra opener. Both outside cans feed half speed and lap back each row, the same as when cultivating.

Several growers also built machines, most of which proved satisfactory. The most practical of these units was built on the rear bar of the regular tractor cultivator and applied fertilizer as the tools on the front bar cultivated. Five openers were used on this four-row machine. The outside cans fed half as much fertilizer as the others, and the machine lapped back each round while cultivating. Several types of shoe and one disk opener were tried on these units, and the one adopted was similar to the shoe designed by Jones (*4*). It was found, however, that even this narrow shoe, which was less than three-fourths of an inch thick, when travelling at speeds higher than 4 miles per hour moved enough dirt to cover small beets 10 inches away. Grinding off the two "left wings" on the diamond point partially corrected this, but it was necessary to shield the row when side-dressing very small beets. Covering of beets was not a factor with the machines that side-dressed as the operator cultivated, as it was not possible to operate the cultivator at a high rate of speed. Less dirt was moved when the shoe was placing the fertilizer 4 inches deep than when it was adjusted for shallow operation. All fertilizer was drilled from 3 to 4 inches deep in the center between the beet rows.

To check the results obtained in 1944 and to try even higher rates of application of nitrogen, one strip test was conducted in 1945 on a field of good fertility. This field had been planted to beets in 1944, and the beet tops plowed under in the fall. An application of 200 pounds of 6-30-0 was applied before seeding in 1945.

In this test nitrogen was applied in one application on May 30, after thinning, ammonium nitrate being the source of nitrogen. Results are given in table 2.

Table 2.—Effect of side-dressing of varying amounts of nitrogen on yield of sugar beets, 1945.

Treatment	Tons per acre
201 pounds nitrogen	22.16
134 pounds nitrogen	19.90
67 pounds nitrogen	18.48
Check, no nitrogen	16.20

At the time the strips were harvested there were three very distinct shades of green in the field, ranging from the very dark green of the heavy treatment to a light green in the strip with the light application. The check was very yellow. The appearance of the two heavily treated strips did not indicate that all of the nitrate had been used or leached through the soil.

Many of the growers who used side-dressing equipment to apply nitrogen left an unfertilized check strip through their commercial fields in 1945. In table 3 are given the acre yields of three of these fields, one being a field low in fertility, the second average, and the third high in fertility. Applications on these fields were made with ammonium nitrate (33.5-0-0).

Table 3.—Grower tests of nitrogen fertilizer, 1945.

	Yield in tons beets per acre		
Treatment	Low fertility Unmanured	Average fertility Unmanured	High fertility Manured
67 pounds nitrogen	5.48	12.81	22.46
Check, no nitrogen	4.23	11.10	21.28
Increase in tonnage	1.25	1.71	1.18
Percent increase	29%	15%	5%

Results of these trials indicate that the farmer with average fertility land made a larger increase in tonnage than the grower with very low or very high fertility fields. The percentage increase was higher in the low fertility field, but the percentage return on the fertilizer dollar invested was less.

One grower side-dressed 67 pounds of nitrogen in two applications. The first application of 33½ pounds was applied just after thinning, and the second application of a like amount was applied in the final cultivation. Although no data from this grower test was obtained, it appears reasonable that in using very large amounts of nitrogen per acre, especially in the form of ammonium nitrate, two lighter applications should be made during the growing season rather than one heavy early application. Carlson (*2*) and Gardner and Rob-

ertson (*3*) both concluded that beets make their great demand for nitrate in August and September and assimilate more nutrients during those 2 months than during any other similar period. It is important to have adequate nitrate available during July and August, and this could be accomplished by spreading the side applications of nitrogen over a longer period of time.

Discussion

The results of preliminary tests indicated increased yields could be obtained by a moderate application of nitrogen fertilizers. These tests stimulated such wide interest among growers that in 1945 about 3,000 acres of beets were side-dressed, mostly with ammonium nitrate, at an average rate of 67 pounds of nitrogen per acre. This represents a substantial portion of the Missoula factory acreage.

Although purities on individual fields were not obtained, the indications are that nitrogen applied during the 1945 season did not have a detrimental effect on the quality of the beets. Purity of juice was 88.4 in 1945 as compared to the 8-year factory average of 88.7. The average sugar percentage for the Missoula factory was the highest of the five factories in the state of Montana, and was 0.19 percent above the past 8-year factory average.

In the light of the foregoing it is of interest to note the conclusions of Ulrich (*5*): "In some environments, beets high in nitrogen may also be high in sugar, and likewise in another environment beets low in nitrogen could be low in sugar. The conditions which favor the storage of sugar by beets, even when the nitrogen supply is high, would occur in localities where sunlight is intense, the days warm to hot, and the nights cool. Under these conditions, photosynthesis would be at a maximum, and respiration would be at a minimum, thus resulting in the formation of sugar faster than it can be utilized to form new tissues (leaves and roots), even when large amounts of nitrogen are available for growth. (Other nutrients are assumed to be adequate)." These qualifications all apply to western Montana, where there are cool nights and long, warm days with intense sunlight.

Looking ahead to 1946, there is a strong possibility that well over half of the beet acreage for the Missoula factory will be side-dressed with nitrogen fertilizers. In the Bitter Root Valley the percentage will be much higher. For 1946 experimental work it is planned to conduct tests with both ammonium nitrate and ammonium sulphate as to the most efficient source of nitrogen and the timeliness and rate of application. Tests with other fertilizer combinations will also be made.

Summary and Conclusions

A nitrogen deficiency exists in many beet fields in western Montana in the lighter-textured soils. Field tests conducted in 1944 demonstrated applications of more than 20 pounds nitrogen per acre produced the most profitable increases in beet yield. In 1945 about 3,000 acres of beets were side-dressed with ammonium nitrate or ammonium sulphate, the average application being 67 pounds nitrogen per acre. With the greater availability of side-dressing equipment, nitrogen will be applied in lesser amounts in two or three applications during the early part of the growing season to reduce losses due to leaching and to make for a more balanced feeding of the plant. Nitrogen applied to fields of low, average, and high fertility levels produced largest increases in beet yields from fields of average fertility. The percentage sucrose and purity were not affected adversely because of nitrogen fertilization. A very material increase in the use of nitrogen will be made in the fertilization of the beet crop in western Montana in 1946.

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Response to Nitrogen and Phosphate Fertilizers in the Intermountain Area

BION TOLMAN[1]

The question of soil fertility is broad in scope and includes a great many different farming practices such as crop rotation, the use of barnyard manure, the use of green manures, the use of commercial fertilizers, judicious use of irrigation water, and the utilization of crop residues. Neglect or abuse of any one of these factors may result in a gradual decline in soil fertility to the point where crop production is no longer profitable.

In many of our sugar beet producing areas the growing season is comparatively short and it is important that the young beet plant become established early and that early leaf and root development be rapid. Then, if maximum yields are to be obtained, the beet must be kept growing at a maximum rate. Adequate supplies of nitrogen and phosphorus favor rapid plant growth and development. In the area covered by the tests reported in this paper these are the two elements which are most frequently limiting factors.

The purpose of the fertilizer tests conducted in Utah, Idaho, South Dakota, and Washington during the 1945 season was to determine the relative deficiency of nitrogen and phosphorus on farms producing sugar beets and to obtain information from which recommendations for commercial fertilizer practices could be based.

Experimental Methods

Grower strip tests were run in each factory district. These tests consisted of plots 16 rows wide and of sufficient length to give a 5- to 6-ton load from each treatment. Each test included both nitrogen and phosphate fertilizers. Nitrogen was supplied by using ammonium sulphate, and phosphate was supplied by using treble-superphosphate. These two fertilizers were applied alone and in combination with varying rates of each fertilizer. The amounts of each fertilizer compared both alone and in combination were: None, 200 pounds per acre, and 400 pounds per acre. The complete combination of fertilizers included in each test may be seen in the tables.

The fertilizers were applied with a side-dresser within 2 to 3 weeks following thinning. Generally the fields were watered within a week to 10 days of when the fertilizer was applied.

At harvest time the beets from each treatment were hauled to the

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dump and the average tare percentage from the entire plot was applied to each treatment. No attempt will be made to make a detailed tabular report of each of these 55 tests. However, a general summary of the results from each is given.

Experimental Results

General Summary of Results from Tests.

There were 18 tests in Utah, 21 in Idaho, 8 in South Dakota, and 8 in Washington.

There were significant responses to fertilizer applications in 14 of the 18 tests in Utah. In only one instance did the most profitable response occur from the use of phosphate alone. In eight of the tests it was more profitable to apply 400 pounds of ammonium sulphate per acre than to apply 200 pounds of the same fertilizer. Net returns per acre from increased yields ranged from $4.27 to $78.08 per acre and averaged $22.23 per acre.

There were significant responses to commercial fertilizer applications in 18 of the 21 tests in Idaho. In only two tests did the most profitable response occur from the use of phosphate alone. In 12 tests 400 pounds of ammonium sulphate was more profitable than a smaller amount. The net return per acre from the increased yields varied from $8.16 to $35.63 per acre. The average net return was $19.41 per acre.

There were significant responses in five of the eight tests in South Dakota. In one test the greatest and most profitable response resulted from the application of 400 pounds of phosphate fertilizer per acre. This farm was the most heavily manured farm in the Belle Fourche district. In the other tests applications of ammonium sulphate up to 400 pounds were profitable. Net returns from increased yields varied from $4.00 to $35.50 per acre and averaged $16.84 per acre. Lack of response on two fields was due largely to insufficient irrigation.

There were significant responses in yield from all the tests in Washington. In only one test did the greatest responses come from phosphate alone. This was a very heavily manured farm which illustrates again that phosphate fertilizers are needed to balance out a manure program. In all but one test 400 pounds of ammonium sulphate gave profitable increases over that obtained with 200 pounds of ammonium sulphate. The net return per acre from increased yields ranged from $8.84 to $76.96 per acre and averaged $37.45.

These tests point out the importance of following a balanced fertilizer program to insure maximum returns for money invested. Recommended fertilizer practice in the Utah-Idaho Sugar Company area includes the use of a mixed fertilizer of 16-20-0 composition with recommended amounts varying from 300 to 600 pounds per acre, depending on the area and the farmer's manure program.

Types of Response

In general the response from the fertilizers applied could be classified into three types: 1. Response from both nitrogen and phosphate fertilizer, with the greatest response occurring where the two were applied in combination; 2. Response to nitrogen only, indicating that there was sufficient phosphate present to satisfy plant requirements completely; and 3. Response to phosphate only, indicating that there was sufficient nitrogen present to satisfy plant requirements.

Examples of tests which gave a response to both nitrogen and phosphate fertilizers are given in table 1. The data indicate that in these tests where there was response from both nitrogen and phosphate fertilizers when these were applied separately, the response was additive when the two fertilizers were applied in combination. Frequently the response was greater than the additive response of the two applied alone. In almost all cases 200 pounds of treble-superphosphate per acre provide a better balance between nitrogen and phosphate than did the 400 pound application. This was shown by the fact that yields averaged 1 ton per acre less when 400 pounds of treble-superphosphate was applied than when 200 pounds was applied. It is not known whether this would have continued to be true if the application of ammonium sulphate had been increased to 600 or 800 pounds per acre. Of the combinations tried 400 pounds of ammonium sulphate and 200 pounds of treble-superphosphate per acre was the most profitable.

Examples of tests which gave response to nitrogen only are given in table 2. The data indicate that there was sufficient phosphate present to satisfy the demands of the plant but that nitrogen was definitely a limiting factor in plant growth. Under these conditions applications of additional phosphate either gave no response or actually decreased yields. For example: On the basis of the average of the eight tests applications of 400 pounds of ammonium sulphate per acre increased yields 3.36 tons per acre, but application of 400 pounds of treble-superphosphate per acre decreased yields an average of .77 tons per acre. In every case the decrease due to applications of phosphate fertilizer was in proportion to the increase from applications of nitrogen fertilizer. It would appear that nitrogen deficiency became more severe as the phosphate level was raised. Under these conditions applications of nitrogen fertilizer alone gave a better balance and greater increase in yield than did combined applications of nitrogen and phosphate fertilizers.

The importance of keeping fertilizer elements in balance was also indicated by the tests which responded to phosphate fertilizers but

Table 1.—Tons beets per acre, showing the individual and combined response of nitrogen and phosphate fertilizers.

Location of test	Amount of Nitrogen and Phosphate Fertilizer applied per acre									[1]Maximum increase in tons per A.	Net return[2] per acre from most profitable increase in yield
	N.	None	200	400	None	None	200	400	200	400		
	P.	None	None	None	200	400	200	200	400	400		
Utah and Idaho												Dollars
Ralph Harmer		17.37	18.46	18.57	17.38	18.14	19.22	20.26	18.79	19.44	2.89	16.79
W. E. Bennion		23.02	24.08	26.16	24.02	23.34	24.91	26.96	26.88	25.74	3.94	28.34
Lester Herndon		14.45	15.02	15.57	14.82	15.23	16.29	16.62	15.64	15.45	2.17	8.87
V. C. Webb		10.79	12.99	15.07	13.80	12.68	13.75	16.54	14.00	15.69	5.75	48.25
Glen Johnson		10.85	12.14	13.82	11.73	11.45	13.23	14.34	13.72	14.24	3.49	23.39
Washington												
Hilmer Nielson		26.95	30.77	31.45	29.98	28.64	31.78	33.08	.....	29.49	6.13	52.32
John Golob		21.29	24.36	27.67	23.64	25.26	28.04	29.65	24.19	29.83	8.54	76.96
Hilsop Sheep Co.		24.05	27.26	25.62	25.80	26.73	27.39	28.05	25.58	26.33	4.00	29.00
Wm. Schilperoot		25.98	26.47	26.88	24.52	24.83	27.70	29.08	28.37	28.16	3.10	18.99
Average		19.53	21.17	22.13	20.62	20.67	22.34	23.00	20.98	22.63	4.07	29.77

N=Pounds per acre of nitrogen fertilizer (ammonium sulphate).
P=Pounds per acre of phosphate fertilizers (treble superphosphate).
[1]May or may not be most profitable treatment.
[2]May or may not be largest increase in yield due to fertilizer application. Cost of fertilizer and harvesting costs deducted from profit figure.

which gave no response to nitrogen fertilizer. Examples of this type of response are given in table 3. It is evident that these tests indicate a condition in which just the opposite relationship is indicated from those in table 2. From the average of these four tests, 400 pounds of treble-superphosphate per acre gave an average of 2.29 tons of beets per acre, but applications of 400 pounds of ammonium sulphate per acre gave an average decrease of 1.87 tons per acre.

In each of these tests the initial nitrogen level was high, and additional nitrogen evidently increased the deficiency of phosphate which in each case was the limiting factor. The one thing common to each of these four tests was that the land on which they were located had been heavily manured over a period of several years. The results of these tests stress the fact that phosphate fertilizer is essential in balancing out a manure program.

Discussion

The results of the fertilizer tests conducted in 1945 indicate the importance of having a proper balance between nitrogen and phosphate fertilizers. Raising the level of one element when another was deficient generally resulted in yields lower than those from the unfertilized plots. This result has been recognized by many different workers during the past 100 years.

The importance of a balance of mineral elements was first recognized by Sprengel (*7*)[2]. In 1845 he stated that no matter how favorable all other factors of growth might be, too great a deficiency or too great an excess of any single constituent necessary for the growth of plants would cause the soil to be unproductive. Liebig (*3*) enlarged on Sprengel's ideas and developed the so-called law of the minimum. According to this law the deficiency of one nutrient element in the soil retards the assimilation of other nutrient elements below the limits obtainable under conditions of most favorable growth. It has been shown by subsequent investigators that the absorption of increasing amounts of nutrient elements by the crop does not proceed in simple proportions, as assumed by Liebig, but that the law of diminishing returns brings absorption of nutrient and yield of crop to a final maximum beyond which further applications of fertilizer are not only ineffective but may be injurious. In 1909 Mitscherlich (*4*) published the results of his work and showed growth curves for each of the nutrient elements for several crops. He also found that if too great an addition of one element was combined with too great a deficiency of another element a condition of unbalance was produced that led to a decrease instead of an increase in yield. In 1927 Lagatu and Maume

[2]Italic numbers in parentheses refer to literature cited.

Table 2.—Tons beets per acre, showing response to nitrogen fertilizer on fields where there was no deficiency of phosphate. Applications of additional phosphate actually decreased the nitrogen response.

	Amount of Nitrogen and Phosphate Fertilizer applied per acre									[1]Maximum increase in tons per A.	Net return[2] per acre from most profitable increase in yield
N.	None	200	400	None	None	200	400	200	400		
Location of test P.	None	None	None	200	400	200	200	400	400		
Utah and Idaho											Dollars
Karl Webb	12.49	14.25	15.36	12.25	12.44	13.49	12.90	13.80	13.90	2.87	26.66
Jesse Dye	12.68	14.39	16.02	12.11	11.38	14.31	15.03	14.60	15.63	3.34	26.93
Eli J. Webb	11.25	14.38	15.31	11.88	9.05	12.50	14.87	12.50	13.44	4.06	34.85
E. C. Rhodehouse	12.37	13.12	14.44	13.33	11.88	11.53	13.02	12.74	13.29	2.07	12.97
E. M. Bacon	9.98	11.56	12.18	9.96	10.24	11.80	11.65	11.82	11.88	2.20	14.40
So. Dakota											
Geo. Jeffrey	9.53	11.68	12.01	10.49	10.01	11.01	11.27	10.60	10.90	2.48	19.96
Washington											
Maurice Rowe	15.19	18.00	18.81	15.48	14.59	16.81	18.74	18.74	18.67	3.62	30.01
Oscar Syverson	20.56	25.03	26.76	19.42	18.32	22.51	25.89	23.73	26.19	6.20	58.40
Average	13.00	15.30	16.36	13.11	12.23	14.24	15.42	14.81	15.48	3.36	27.16

N=Pounds per acre of nitrogen fertilizer (ammonium sulphate).
P=Pounds per acre of phosphate fertilizer (treble superphosphate).
[1]May or may not be most profitable yield.
[2]Calculated from most profitable treatment. Cost of fertilizer and harvesting costs deducted from profit figure.

Table 3.—Tons beets per acre, showing response to phosphate fertilizer on fields where there was sufficient nitrogen. Applications of additional nitrogen actually depressed the phosphate response.

	Amount of Nitrogen and Phosphate Fertilizer applied per acre											
	N.	None	200	400	None	None	200	400	200	400	[1]Maximum increase in tons per A.	Net return[2] per acre from most profitable increase in yield
Location of test	P.	None	None	None	200	400	200	200	400	400		
Utah and Idaho											Tons	Dollars
Carl Marcuren		15.36	14.87	14.87	15.81	16.75	17.86	16.77	16.19	16.28	2.50	17.40
S. H. Blake		23.40	22.53	22.87	23.41	25.07	25.89	24.48	25.31	25.16	2.49	17.29
So. Dakota												
Fred Kiel, Sr.		7.82	6.60	6.67	9.93	11.65	10.98	10.39	9.29	10.74	3.83	35.50
Washington												
Maurice Rowe		28.90	24.44	23.59	28.81	31.18	29.04	31.74	28.00	29.02	2.28	14.68
Average		18.87	17.11	17.00	19.49	21.16	20.94	20.84	19.69	20.30	2.29	14.79

N=Pounds per acre of nitrogen fertilizer (ammonium sulphate).
P=Pounds per acre of phosphate fertilizer (treble superphosphate).
[1]May or may not be most profitable yield.
[2]Calculated from most profitable treatment. Cost of fertilizer and harvesting costs deducted from profit figures.

(*2*) published work in which they correlated studies using balanced and unbalanced fertilizers with chemical analyses of leaves of the plants being studied. Their experiments showed that an excess of some nutrients diminished the absorption of a deficient element to the point that there was less of it in the plant than was present when the plant was grown on unfertilized soil. The general effect of the increase of one element in the nutrient solution was to cause a decrease in the leaf content of the other two elements measured. This work was substantiated by Thomas (*8*) who used foliar diagnostic methods in his work with complete and unbalanced fertilizers on potatoes. This type of correlated work was carried further by Opitz, Rothsack and Margenroth (*5*) in Germany. They worked with barley and used varying rates of potash, phosphorus, and nitrogen fertilizers both separate and in combination. These investigators analyzed the total plant and found essentially the same thing as did Lagatu and Maume (*2*), i. e. applications of unbalanced fertilizers produced yields of crop inferior to those obtained from an unfertilized plot. Browne (*1*) summarizes the work of several investigators by stating that the mineral composition of plants can be affected only within certain limits. An increase of one constituent is offset by the decrease of another. Too great an excess as well as too great a deficiency of a particular nutritive element brings with it injury to the crop, which is reflected in lowered vitality and diminished yield.

In view of the fact that one element cannot be substituted for another and that an excess of one nutrient element actually interferes with the proper utilization of others, it becomes of increasing importance that fertilizer recommendations be based on comprehensive information and that fertilizer practice be adapted, insofar as possible, to meet the needs on each individual farm. To meet this problem, fertilizer studies should include a study of soil type, cropping history, fertilizer and cultural practices, and demands of the crop being grown. Schreiner (*6*) summarizes this problem as follows: "Evaluation of the fertility of a soil and of the quality and quantity of a fertilizer required for profitable yield and quality of crop is indispensable to economic fertilizer usage and essential to efficient crop production. Three general types of procedures are being used for this evaluation—plot tests with specific crops in the field, pot tests with field crops or selected test crops, and laboratory procedures involving chemical and biological factors."

Probably no one of these procedures is best under all conditions, and probably all three types of tests can advantageously be used in surveying fertilizer requirements.

Summary

Field tests with nitrogen and phosphate fertilizers conducted in Utah, Idaho, South Dakota, and Washington indicated a general deficiency of nitrogen and phosphate. On many farms the nitrogen level was so low that applications of phosphate not only gave no response but actually decreased yields. In a few cases phosphate was so deficient that applications of nitrogen fertilizer alone injured the crop. These cases generally occurred where the farmer had been following a heavy manure program. On farms where there was a response to both nitrogen and phosphate fertilizers, the yield increase on plots receiving both fertilizers was greater than the combined increase of the two added separately.

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Influence of Crop-Sequence and Fertilizers Upon the Sugar Beet Crop

J. G. LILL[1]

Beginning in 1935 and continuing until the end of 1943, the Division of Sugar Plant Investigations of the U. S. Department of Agriculture cooperated with the Ohio State Agricultural Experiment Station in an experiment designed to determine the influence of certain crops grown in one season upon the same crops when grown on the same soil during the following season. The experimental plan was changed in 1939 to include applications of commercial fertilizer each year to one-half of each crop plot.

The crops included in this experimental work were sugar beets, corn, oats, soybeans for hay, and soybeans for seed. One primary objective was to determine the influence of the sugar beet crop upon the crops grown following it; another was to determine the influence of the other crops upon the yield and quality of the sugar beet roots when the sugar beet crop was grown following the other crops; and a third objective was to determine whether the effects of the crop-sequence upon the yield and quality of the sugar beet roots were modified by the application of commercial fertilizer.

Previous reports (*1*, *2*)[2] have described the plan of the experiment, the area where the work was located, the manner in which the work was carried on, and the yields obtained from the various crops included, as influenced by the crop-sequence and fertilization factors. Although the yields obtained from the various crops have already been reported in the articles referred to, additional data that have not been reported were taken on the sugar beet roots produced under the various crop-sequence and crop-sequence-fertilization conditions, and it is the purpose of this report to present all such information pertaining to the sugar beet crop.

The only way the effect the sugar beet crop had upon the yields of the following crop could be determined was by comparing the yields obtained from the crops when grown following sugar beets with the yields obtained from the same crops when grown under like conditions but following other crops. A summary of these results is given in table 1 where it will be noted that the crop-sequence influence of the sugar beet crop varied according to the crop grown following it. When sugar beets were grown following sugar beets, the yield obtained was

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[2]Italic numbers in parentheses refer to literature cited.

Table 1.—The crop-sequence influence of sugar beets.

When the experimental crop was grown following:	The average acre-yield of the indicated crop when grown following sugar beets and the average acre-yield of the same crop when grown following all the crops except itself and sugar beets.				
	Sugar beets	Corn	Oats	Soybean hay	Soybean seed
	tons	bushels	bushels	tons	bushels
AVERAGE YIELDS FOR SEVEN CONSECUTIVE SEASONS WHERE NO FERTILIZER HAD BEEN APPLIED TO THE SOIL					
Sugar beets	5.287	42.31	51.20	2.240	23.91
The other crops*	6.505	40.04	47.35	2.283	24.29
Difference	−1.218	2.27	3.85	−0.043	−0.38
AVERAGE YIELDS FOR THREE CONSECUTIVE SEASONS WHERE FERTILIZER HAD BEEN APPLIED TO THE SOIL					
Sugar beets	8.891	50.26	65.98	2.360	21.10
The other crops*	10.663	47.32	56.00	2.422	22.51
Difference	−1.772	2.94	6.98	−0.062	−1.41
DIFFERENCES STATED IN PERCENTAGES OF THE MEAN YIELDS OBTAINED FOLLOWING SUGAR BEETS					
Seven seasons results	−23.05	5.37	7.52	−1.92	−1.59
Three seasons results	−19.93	5.85	10.58	−2.63	−6.68

*The average yield of beets following the other four crops and the average yields obtained from the other crops following all the crops except sugar beets and itself, i. e., three crops.

seriously depressed; when the soybean crops were grown following sugar beets, the yields were slightly but not seriously depressed; but when corn or oats were grown following the sugar beets, both the 7-year and the 3-year average yields obtained were somewhat better than the average yields obtained when either of these crops were grown following the other crops included in this experiment. So it would seem, as far as the results of this experimental work are concerned, that the sugar beet crop may be considered a good preparatory crop for either corn or oats; a fair preparatory crop for soybean seed or soybean hay; and a very poor preparatory crop for sugar beets.

The influence of the various crops upon the following sugar beet crop was determined through keeping a record of the numbers of marketable roots as well as of the yields obtained under the various crop-sequence conditions and also through taking samples of the roots produced upon each plot or sub-plot from which the sucrose percentages of the beet roots and the apparent purity coefficients of the beet juices were determined. This information is summarized in table 2 from which it will be noted that the numbers of roots, the acre-yields, the sucrose percentages, and the apparent purity coefficients, and also the calculated amounts of indicated available sugar produced per acre, all differed one from the other under the various crop-sequence conditions

and that with the exception of the apparent purity coefficients, statistically significant differences were found.

In view of the fact that with the exception of the crop-sequence conditions, all conditions were kept as nearly uniform as possible for the sugar beet crop during the course of this experimental work, such differences in numbers, in acre-yields, and in quality of the beet roots obtained are attributable to the differences in the crop-sequence conditions under which the sugar beet crop was grown.

The differences in numbers of marketable roots obtained under the various crop-sequence conditions are believed to be due largely to a soil sanitation effect of the preceding crops and the difference to be brought about by the fact that some of the crops discourage the growth of pathogenic soil organisms which attack the sugar beet seedlings and plants, whereas other crops either do not discourage the growth of such organisms or may actually favor it, thus creating conditions unfavorable to obtaining adequate stands of sugar beets. According to the results presented in table 2, the soybean and corn crops created a more favorable soil condition for the sugar beet seedlings and plants

Table 2.—The sugar beet crop as influenced by the crop-sequence factor.

When the sugar-beet crop was grown following	Characteristics of the sugar-beet crop when grown following the crop indicated.				
	Marketable roots per acre	Acre-yield	Sucrose	Apparent purity coefficient	Calculated production of indicated available sugar per acre
	number	tons	percentage		pounds
AVERAGE RESULTS FOR SEVEN CONSECUTIVE SEASONS OBTAINED WHERE NO FERTILIZER HAS BEEN APPLIED TO THE SOIL					
Sugar beets	11712	5.287	15.22	84.11	1352
Corn	14753	6.020	15.91	85.53	1624
Oats	13842	5.891	15.69	85.55	1500
Soybean hay	14318	7.275	15.84	85.31	1988
Soybean seed	15368	6.833	15.78	85.68	1825
With difference[1]	990**	0.616**	0.37*	1.21	177**
AVERAGE RESULTS FOR THREE CONSECUTIVE SEASONS OBTAINED WHERE FERTILIZER HAS BEEN APPLIED TO THE SOIL					
Sugar beets	13158	8.363	15.21	84.41	2062
Corn	16812	9.396	16.26	85.73	2558
Oats	16235	9.190	15.96	85.59	2489
Soybean hay	17138	11.580	16.06	85.57	3160
Soybean seed	17594	10.476	15.98	85.19	2804
With difference[1]	1757*	1.221**	0.51**	1.17	379**

[1] Difference necessary for significance at the 5-percent level.
* Differences statistically significant to the 5-percent point.
** Differences statistically significant to the 1-percent point.

than did the oat crop, and the oat crop created a much more favorable condition for the beet plants than did sugar beet plants themselves.

Although the acre yields of sugar beet roots obtained under the various crop-sequence conditions were different, as shown in table 2, when the rankings of the yields and the numbers of marketable roots are compared it becomes evident that the yields, being so nearly in the same order as the numbers of marketable roots, were determined very largely by the numbers of marketable roots obtained. If the yields obtained were determined entirely by the numbers of marketable roots, it might be expected that the average weights of the roots produced under the various crop-sequence conditions would be nearly the same, or since it is well known that with all other conditions being equal there is a negative relationship between the number of roots produced upon a given area and the average weight of those roots, that the ranking of the average weights of the roots produced would be the exact reverse of the ranking of the numbers and that there would be a straight-line relationship between the numbers of marketable roots and the average weight of the roots. So far as the average weights of the roots produced in this experimental work are concerned, neither assumption is entirely correct. When the average weights of the roots are plotted against the numbers as is shown in figure 1, it will be seen that there is a negative and approximately straight-line relationship between the numbers of roots and the average weights of the roots produced by those beets grown following the sugar beet, corn, and oat crops as shown by the solid lines in figure 1, but that the average weight of the roots produced following the soybean crops, as shown by the broken lines, do not abide by the same rule. It must be concluded therefore that the growth of the soybean hay and soybean seed crops upon the soil during one season benefited the sugar beet crop of the following season not only in the numbers of marketable roots obtained but also in the average weights of the individual roots.

A summary of the sucrose percentages of the beet roots and the apparent purity coefficients of the beet juices, as determined by the analysis of the samples taken from each of the plots or sub-plots under each of the crop-sequence conditions, revealed that differences did exist in the quality of the beet roots harvested. However, so far as statistical significance or appreciable difference is concerned, this difference in quality was entirely between those sugar beet roots produced following sugar beets and those beet roots produced following any of the other crops. The sugar beet roots produced on the soil which had produced sugar beets during the preceding year were definitely lower in quality than the beet roots produced following any of the other crops.

Beginning with the season of 1939, a fertilization factor was in-

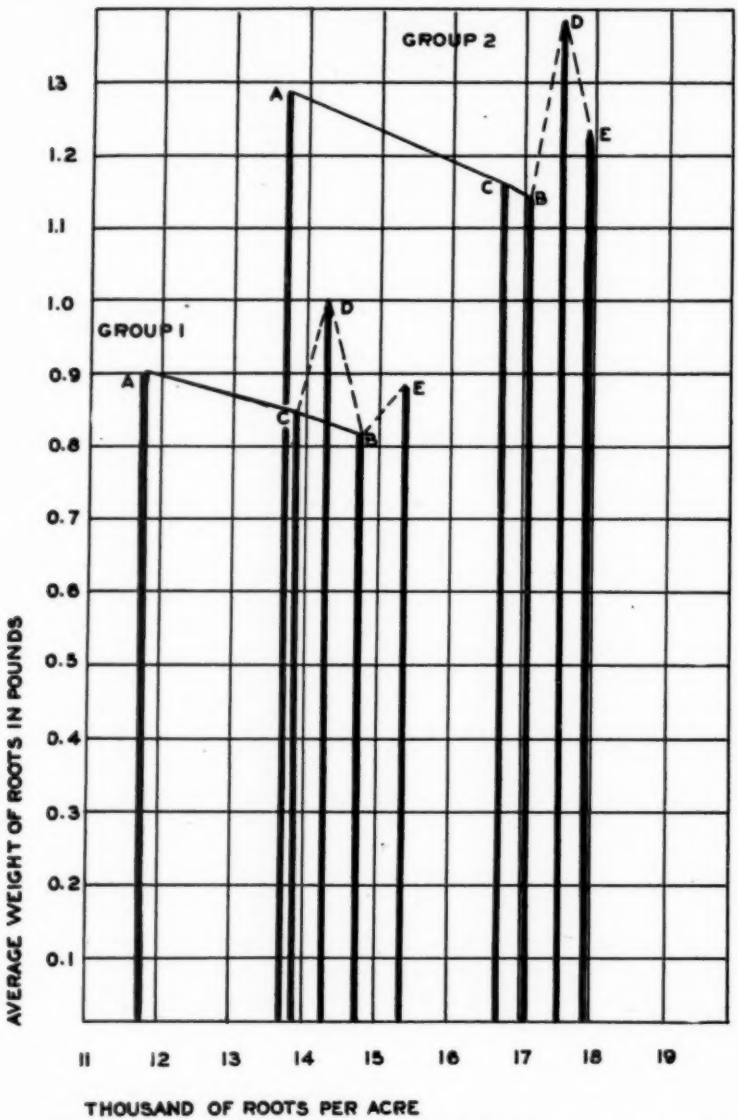

Figure 1.—Number and average weight of roots produced under the various crop-sequence conditions. Group 1. Results obtained during seven consecutive seasons where no fertilizer had been applied. Group 2. Results obtained during three consecutive seasons where fertilizer had been applied.

The preceding crops were: A, sugar beets; B, corn; C, oats; D, soybean hay; E, soybean seed.

troduced into the experimental plan. This was accomplished through the application of 300 pounds per acre of a 4-10-6 fertilizer mixture to one half of each of the crop strips each season. In even numbered years the west half of each crop strip received the application of fertilizer and in the odd numbered years, the north half of each crop strip was fertilized. This resulted in each crop-plot being divided into four sub-plots according to the fertilization conditions which can be designated as:

Fertilized both current and preceding years,
Fertilizer current but not preceding year,
Fertilized preceding but not current year,
Fertilized neither current nor preceding year.

The results were recorded according to both the crop-sequence condition and the fertilization condition under which they were obtained.

It was possible to determine from the results obtained under the various fertilization conditions if the crop-sequence effect had been modified in any way by the fertilization. The statistical analysis of the data obtained, as reported previously (*1*) did show that there was an interaction between the crop-sequence influence and the fertilization factor with significance to the 5 percent level when the acre yields were considered but that there was no interaction discernible so far as the numbers of marketable roots, sucrose percentages, or apparent purity coefficients were concerned. The fertilization conditions did, however, modify the numbers of marketable roots and the yields obtained and also the quality of the roots as shown in table 3 and figure 2. From this table it will be noted that higher numbers of marketable roots, better acre-yields, and better quality roots were obtained when the fertilizer had been applied to the sugar beet crop in the current year than when it had been applied to the preceding crop; and the results were better when the fertilizer had been applied to the preceding crop than when none had been applied. The average size of the sugar beet roots obtained as shown in figure 2, became larger with the increase in the fertilization factor, in spite of the greater number of marketable roots being produced upon a given area.

The sugar beet crop has been grown in the eastern agricultural areas for more than 50 years. In those sections where yields have been satisfactory and where factories have been established, the sugar beet crop has been adopted and has been incorporated into the cropping systems being followed. However, even in these sections, opinions and beliefs are often encountered which credit the sugar beet crop with exerting a deleterious effect upon the soil and thus upon the yield to be obtained from the crop following. The results obtained in this experimental work which, for that part which did not include fertiliza-

Table 3.—Effect of the fertilization conditions upon the yield and quality of the sugar beet roots.

When grown where 300 pounds per acre of a 4-10-6 fertilizer mixture had been applied when indicated	Characteristics of the sugar beet crop when grown under the various fertilization conditions				
	Marketable roots per acre	Acre-yield	Sucrose	Apparent purity coefficient	Calculated production of indicated available sugar per acre
	number	tons	percentage		pounds
Current and preceding years	17011	10.979	16.05	85.31	2945
Current but not preceding year	17008	10.370	16.12	85.58	2800
Preceding but not current year	15858	9.577	15.73	85.17	2521
Neither current nor preceding year	14874	8.285	15.69	85.12	2183
With difference [1]	528**	0.418**	0.31*	0.86	144**

[1] Differences necessary for significance at the 5-percent level.
* Differences statistically significant to the 5-percent point.
** Differences statistically significant to the 1-percent point.

tion, was carried on through seven consecutive seasons and through three consecutive seasons for that part which did include fertilization, indicate very definitely that the sugar beet crop does not exert a generally deleterious effect upon the soil as reflected by the yields obtained from the crops following. In fact it was only when sugar beets were grown following sugar beets that a definite deleterious effect was found. When other crops were grown following the sugar beet crop, no appreciable deleterious effect was found and in the case of two of the crops commonly included in many rotations throughout the eastern agricultural areas, the crop-sequence influence of the sugar beet crop was found to be beneficial.

The sugar beet crop was also found to respond quite favorably to the fertilization factor. Not only were the numbers of marketable roots and the yields increased by the application of fertilizer, but the quality of the roots was also bettered. These benefits, each of which may not be so very great in itself, are combined in the objective of the crop—the amount of recoverable sugar indicated per acre—and the total difference caused by the fertilization is found to be very appreciable.

The results to be obtained from the sugar beet crop are found to be definitely influenced by the crop-sequence effect of the crop preceding it. This crop-sequence effect was apparent in the numbers of marketable roots, average weight of the roots obtained, the yield, and also the quality of the roots produced. The benefits to be derived from

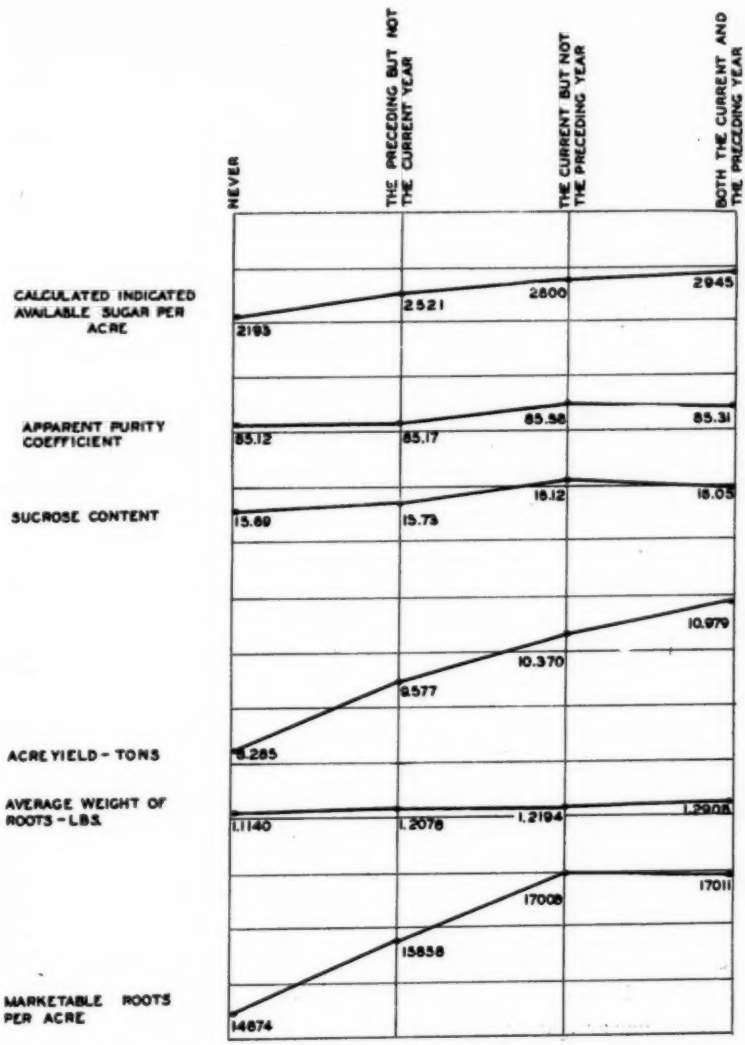

Figure 2.—Response of sugar beets to applications of fertilizer when 300 pounds per acre of a 4-10-6 mixture had been applied as indicated. Three seasons data.

favorable crop-sequence conditions with the sugar beet crop can be obtained without additional expense in the production of the crop and hence should be given careful consideration.

The results obtained in this experimental work have shown that the success of the sugar beet crop is influenced both by the crop-sequence conditions under which it is grown and also by the fertilization of the soil. The results indicate, however, that the two factors operate practically independently of each other in exerting their influence upon the sugar beet crop. In the statistical analysis of the data, it was determined that only in the case of the yields was the crop-sequence effect modified to any extent by the fertilization factor and this modification was relatively slight, being only of the 5-percent order of significance. With all the other characteristics of the crop, the two factors were found to be independent of each other. Thus it may be concluded that the handicap derived from a poor cropping system with the sugar beet crop cannot be offset by a good fertilization program nor can the benefits to be derived from needed fertilization be nullified by a good crop-sequence condition.

From the material presented in this report it may be concluded that:

1. The sugar beet crop may be a good or a fair preparatory crop according to the nature of the following crop but it does not exert a generally deleterious effect except when sugar beets are grown following sugar beets.
2. The sugar beet crop itself varies in all its characteristics under the influence of the crop-sequence factor.
3. Basing conclusions upon the numbers of marketable roots obtained, soybeans grown for seed, and corn, create conditions within the soil that are favorable to obtaining stands of sugar beets significantly higher than were obtained with other crops. Consideration of the acre-yields obtained indicates that soybeans as grown either for seed or hay brought about conditions favorable for production of sugar beet yields significantly higher than those obtained when sugar beets followed the other three crops in these tests.
4. The quality of the sugar beet roots, as well as the number of marketable roots and acre-yield, is depressed by growing sugar beets following sugar beets.
5. The sugar beet crop responded to the application of fertilizer by an increase in the numbers of marketable roots, by an increase in the average weight of those roots, and by a slight betterment of the quality of such roots.
6. The statistical analysis of the data indicated no modification of the crop-sequence factor effect on the sugar beet crop by the fer-

tilization factor except with the yields where some slight modification was determined. So far as the numbers of marketable roots, sucrose percentages, and apparent purity coefficients were concerned, the two factors apparently operated entirely independently of each other.

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Yield, Percentage of Sucrose, and Coefficients of Apparent Purity of Sugar Beets as Affected by Rotational, Manurial, and Fertilizer Practices at the Dominion Experimental Station, Lethbridge, Alberta

K. W. HILL[1]

The Dominion Experimental Station is located near the city of Lethbridge, Alberta, which is 200 miles northwest of Great Falls, Mont. The Station is approximately in the center of the sugar beet growing area of Southern Alberta which annually produces about 30,000 acres of sugar beets. Nine year production averages (1936-1944) for the area are: Tons of beets per acre, 12.18; percentage of sucrose, 17.85; sugar extracted per ton of beets, 302.76 pounds.

The purpose of this paper is to present information from some of the sugar beet cultural experiments which have been conducted almost continuously through the 4 decades of the Station's existence. The results discussed herein were secured from a long-term rotational experiment which was originally laid down on an old alfalfa field known to have some phosphorous deficiency. This deficiency now has been accentuated to the extent that sugar beet production on some of the check plots is decidedly uneconomic.

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Data from three rotations will be presented, viz.:

8-year alfalfa rotation—alfalfa, alfalfa, alfalfa, wheat, sugar beets, sugar beets, wheat, wheat seeded down to alfalfa.

4-year cereal rotation—wheat, barley, sugar beets, sugar beets.

4-year sweet clover green manure rotation—wheat seeded down to sweet clover, clover hay, sugar beets, sugar beets.

Each rotation was subjected to the following four fertility treatments: Barnyard manure only, phosphatic fertilizer only, both barnyard manure and phosphatic fertilizer, and no fertilization. Green manure plus phosphatic fertilizer, and green manure alone, were two additional treatments used in the green manure rotation.

Materials and Methods

Manure.—In the 8-year rotation 30 tons of barnyard manure per acre were added once in the rotation cycle, and in the 4-year rotations 20 tons of barnyard manure per acre were added once in 4 years. In all cases the weighed quantity of manure was applied to the grain or clover stubble on the appropriate plot and plowed under the fall before planting the first crop of beets in each rotation cycle. The barnyard manure used had originated in the dairy and horse barns on the Station and had been fairly well preserved in large compost piles until the time of application when it contained approximately 50 percent dry matter.

Phosphatic Fertilizer.—Triple superphosphate (0-43-0) was applied to half of each phosphate-treated plot by drilling this fertilizer at the rate of 100 pounds per acre with the seed each year that sugar beets were sown.

Design of Experiment.—The design of the experiment as it was laid down in 1929 was relatively simple. Duplicate plots were selected at random (i. e., for the 8-year rotation 16 plots were required). Each plot was divided longitudinally and the phosphate fertilizer application assigned at random to one side. In addition each plot was bisected transversely and the barnyard manure application assigned at random to one end. Each rotational treatment plot thus quartered included four sub-treatments:

1. 30[2] tons barnyard manure and 100 pounds triple superphosphate per acre.
2. 30 tons barnyard manure only.
3. 100 pounds triple superphosphate per acre only.
4. No manure or fertilizer added.

These sub-treatments have been identified by a 3-figure number. For example, in treatment No. 821 the first digit gives the duration of the rotation in years, the second gives the year of beets in the cycle

[2]In the 4-year rotations the amount is 20 tons.

(either first or second) and the third digit identifies the number of the manurial sub-treatment as listed above. In the 4-year green manure rotation the identification number was prefixed by the letter "G" and two additional treatments were included, namely, No. 5, green manure (second crop of sweet clover plowed under) and 100 pounds triple superphosphate per acre added, and No. 6, green manure only. In the other treatments of this rotation, i. e., Nos. G 411, G 412, G 413, G 414, both crops of sweet clover were taken off for hay.

This experimental design satisfied all biometrical requirements for individual analysis of each rotation. However, the treatments of each rotation were randomized separately on blocks which were not contiguous, although they were very near each other in an extremely uniform field. This fact made a combined analysis of the three rotations somewhat unorthodox. In spite of this weakness in design the results from the three rotations are thought to be strictly comparable.

Experimental Results

Data for the 10-year period 1936-45 inclusive have been summarized, and means for tons of beets per acre, percentage of sucrose, and coefficients of apparent purity are shown in table 1. The results of the statistical analyses are presented in tables 2, 3, and 4.

Discussion of Results

Yield of Roots.—Highly significant differences occurred between yields of roots on the different treatments within each rotation and also less striking differences between some of the comparable treatments in the three rotations.

Yield of Roots as Affected by Manure.—The addition of barnyard manure produced a significant increase in yield over the untreated plots and also over the plots which received phosphate fertilizer alone. This was true in all rotations. Furthermore the significantly beneficial effect of the barnyard manure was carried over into the second year of beets under all manurial treatments. In all rotations the addition of both barnyard manure and phosphatic fertilizer produced higher mean yields than those produced when barnyard manure alone was added. However, the increase was not sufficiently great to be statistically significant. On those crops which were further removed from the year of manure application, significantly higher yields were obtained which were attributable to the phosphatic fertilizer application in addition to manure. This was true particularly of alfalfa.

Yield of Roots as Affected by Phosphatic Fertilizer.—The application of 100 pounds of triple superphosphate per acre in each of the 2 years of sugar beets gave highly significant increases over the check

Table 1.—Ten-year summary means of sugar beets grown at Lethbridge, Alberta, on plots receiving various applications of barnyard manure and phosphatic fertilizer.

Treatments	Root yield per acre (Tons)	Sucrose content of roots (Percentage)	Coefficient of apparent purity (Percentage)
811-30 T/Man & 100 pounds T.S.P.	19.31	15.72	85.81
812-30 T/Man.	18.90	15.75	85.77
813-100 pounds T.S.P.	12.81	15.78	85.84
814-No Additions	3.47	14.90	84.75
Means of first crop	13.62	15.54	85.83
821	19.32	16.26	85.99
822	18.79	16.46	86.24
823	16.05	16.23	85.92
824	5.32	15.33	85.22
Means of second crop	14.87	16.12	85.84
Means of 8-year rotation	14.25	15.83	85.84
411-20 T/Man 100 pounds T.S.P.	19.93	17.30	86.78
412-20 T/Man.	19.26	17.42	86.96
413-100 pounds T.S.P.	13.63	17.09	87.09
414-No additions	6.50	16.54	86.33
Means of first crop	14.83	17.09	86.79
421	19.11	17.18	87.31
422	17.88	16.47	86.18
423	15.07	16.93	86.82
424	7.38	16.73	86.75
Means of second crop	14.86	16.83	86.74
Means of 4-year cereal rotation	14.85	16.96	86.77
G-411	20.36	16.73	86.17
G-412	20.27	16.54	86.57
G-413	15.92	16.35	86.16
G-414	6.34	15.86	86.13
G-415	16.17	16.57	86.18
G-416	7.42	16.13	85.38
Means of first crop	14.41	16.36	86.10
G-421	19.56	17.07	85.78
G-422	17.64	17.06	86.97
G-423	15.26	16.28	85.93
G-424	7.58	16.06	85.63
G-425	15.97	16.54	85.49
G-426	7.50	15.83	85.01
Means of second crop	13.92	16.47	85.80
Means of 4-year G.M. rotation	14.17	16.42	85.95

plots but without barnyard manure maintained only fair sugar beet yields which are continuing to retrogress. The companion crops in the rotation cycle, particularly alfalfa, showed a much poorer relative performance than the sugar beets.

Yield of Roots as Affected by Green Manure.—In the green manure rotation the plots receiving 100 pounds of triple superphosphate per acre as the only addition (Nos. G 413 and G 423) produced considerably higher yields than similarly fertilized plots in the other rotations. This increase may have been attributable to the benefits derived

Table 1 (a).—Comparison of sugar beet yields grown on manured and unmanured plots, and also on fertilized and unfertilized plots under three different rotations at the Dominion Experimental Station, Lethbridge, Alberta. (All figures are 10-year summary means.)

Treatments	Root yield per acre (Tons)	Sucrose content of roots (Percentage)	Coefficient of apparent purity (Percentage)
Eight-year alfalfa rotation			
Average of all manured plots	19.08	16.05	85.95
Average of all unmanured plots	9.41	15.61	85.43
Average of all fertilized plots	16.87	16.00	85.89
Average of all unfertilized plots	11.62	15.66	85.80
Four-year cereal rotation			
Average of all manured plots	19.05	17.09	86.81
Average of all unmanured plots	10.65	16.82	86.75
Average of all fertilized plots	16.93	17.13	87.00
Average of all unfertilized plots	12.76	16.79	86.56
Four-year sweet clover green manure rotation			
Average of all manured plots	19.43	16.85	86.37
Average of all unmanured plots	11.28	16.14	85.96
Average of all fertilized plots	17.78	16.60	86.01
Average of all unfertilized plots	12.96	16.38	86.32
Average of all G.M. & fertilized plots	16.07	16.56	85.83
Average of all green manured plots	7.46	15.98	85.19

from the partial summer-fallow after the second crop of hay was removed. No significant advantage was observed from the plowing under of the second crop of clover as green manure (cf. G 415 vs. G 413 and G 425 vs. G 423).

Yield of Roots on Untreated Plots.—The check plots, which received no barnyard manure or phosphatic fertilizer, yielded as low as one half ton per acre, and extreme difficulty was experienced in securing a satisfactory stand in the spring. Although emergence usually was satisfactory, the seedlings displayed much more susceptibility to seedling diseases and insect injury than did seedlings growing on the fertilized plots.

Percentage of Sucrose.—The percentages of sucrose of beets produced on the various treatments are most interesting although quite at variance with results reported from more southerly areas. First, percentage of sucrose was not depressed by the application of manure, and second, percentage of sucrose was markedly affected by a deficiency of phosphorus.

Percentage of Sucrose as Affected by Manure.—In earlier work at this Station Palmer (*7*)[3] has shown that the percentage of sucrose was not depressed by the annual application of 15 tons of manure per

[3]Italic numbers in parentheses refer to literature cited.

Table 2.—Analyses of variance of yield, percentage of sucrose, and apparent purity of sugar beet roots grown in an 8-year alfalfa rotation on plots variously treated with barnyard manure and phosphatic fertilizer.

Sources of variation	D.F.	Tons of roots per acre		Percentage of sucrose		Coefficient of apparent purity	
		Mean squares	Calculated F values	Mean squares	Caluclated F values	Mean squares	Calculated F values
Between replications	10	9.26		1.67		1.76	
Between years	9	82.84	18.62**	32.52	18.48**	47.35	15.34**
Between crops	1	62.40	14.02**	14.04	7.98*	3.56	
Crops X years	9	26.24	5.90**	2.93		6.54	
Error (a)	10	4.45		1.76		3.08	
Manure vs. no manure	1	3791.84	1723.56**	7.31	9.88**	10.72	4.72*
Fertilizer vs. no fertilizer	1	1103.73	501.70**	4.29	5.80*	6.16	
Manure X fertilizer	1	913.46	415.21**	7.83	10.58**	10.00	4.40*
Treatments X crops	3	7.48	3.4 *	.13		.43	
Treatments X years	27	9.15	4.16**	1.84	2.49**	5.09	
Fertilizer X crops X years	9	14.39	6.54**	2.42	3.27**	2.75	
Manure X crops X years	9	5.10	2.32*	.48		1.81	
Error (b)	69	2.20		.74		2.27	
Total	150						

*—Exceeds the 5 percent point of significance.
**—Exceeds the 1 percent point of significance.

Table 3.—Analyses of variance of yield, percentage of sucrose, and apparent purity of sugar beet roots grown in a 4-year cereal rotation on plots variously treated with barnyard manure and phosphatic fertilizer.

Sources of variation	D.F.	Tons of roots per acre		Percentage of sucrose		Coefficient of apparent purity	
		Mean squares	Calculated F values	Mean squares	Caluclated F values	Mean squares	Calculated F values
Between replications	10	14.40		1.18		2.64	
Between years	9	72.87	11.49**	21.08	4.33*	30.24	17.58**
Between crops	1	.03		2.65		.01	
Crops X years	9	17.68		.65		1.28	
Error (a)	10	6.34		4.87		1.72	
Manure vs. no manure	1	2822.98	559.01**	2.92		.20	
Fertilizer vs. no fertilizer	1	698.68	138.35**	4.49	4.45*	7.88	4.53*
Manure X fertilizer	1	418.19	82.81**	.06		.003	
Treatments X crops	3	18.08	3.58*	2.33		3.82	
Treatments X years	27	5.40		.97		1.67	
Fertilizer X crops X years	9	7.04		1.07		3.33	
Manure X crops X years	9	3.01		8.37	8.29*	.65	
Error (b)	69	5.05		1.01		1.74	
Total	150						

*—Exceeds the 5 percent point of significance.
**—Exceeds the 1 percent point of significance.

acre to sugar beets for 7 consecutive years. Average results for 7 years are shown in the subjoined table 4:

Table 4.—Yield, percentage of sucrose, and coefficients of apparent purity of beets grown on plots variously treated with manure and fertilizer.

Treatment	Tons per acre	Percentage of sucrose	Coefficient of apparent purity
15 tons manure per acre annually	21.53	17.0	85.2
15 tons manure and 100 pounds triple superphosphate	22.61	17.1	86.9
100 pounds triple superphosphate only	16.06	16.9	87.1
No additions	8.86	16.6	85.6

The data in table 4 do not agree with results reported by Nuckols (*5, 6*) in Nebraska or with the work of many other investigators. However, it is felt that this contrariety can be understood in some measure in view of the difference in climate between the localities. The extensive photoperiod of Southern Alberta (latitude 49½°) and other climatic differences have generally been given credit for the fact that sugar production per acre in Alberta ranks favorably with any of the States of the Union except California, despite a growing period which is up to 1 month shorter than that of many areas of Idaho, Utah, or Colorado.

The comparatively high percentage of sucrose in beets grown in Alberta has been in evidence since the inception of the industry in this locality. This favorable condition is usually explained by reference to the combination of photoperiodism and other climatic factors, such as cool fall weather, which seem to be exceptionally well suited to the synthesis of sucrose. It has been suggested that because of these conditions beets are able to utilize relatively large quantities of plant nutrients and this utilization is expressed in the production of sucrose at a comparable rate with the production of tissue. Under less favorable climatic environment the presence of extensive nutrients brings about increases in size of beet while synthesis of sucrose fails to show a commensurate gain. Under Alberta conditions it appears that any improved agronomic practice such as manure application or better distribution of irrigation water which is reflected in better than average yields does not necessarily depress sucrose percentage below the average. In fact the weight of available evidence in Alberta seems to indicate that the sucrose percentage is increased as the yields are increased above the average by better field husbandry.

Percentage of Sucrose as Affected by Phosphorus.—Minimum significant differences between rotations have not been calculated because of the limitations of the experimental design mentioned above. However, the superiority of the percentage of sucrose of the 4-year

cereal rotation over the 8-year alfalfa rotation is so consistent that its interpretation as real even without benefit of statistical significance seems justified.

The mean percentage of sucrose for these two rotations is compared below by years:

	1936	1937	1938	1939	1940
8-year rotation	16.02	15.06	15.44	15.08	13.70
4-year rotation	16.09	16.24	17.64	15.63	16.15
	1941	1942	1943	1944	1945
8-year rotation	17.01	17.64	13.97	17.70	16.74
4-year rotation	17.72	17.25	16.14	19.47	17.25

The fact that the 8-year alfalfa rotation as a whole displayed an apparently significantly lower sucrose percentage than the 4-year cereal rotation while the yields were strictly comparable has proven rather difficult to explain.

It will also be noted that the first year of beets on the alfalfa rotation displayed a significantly lower percentage of sucrose than the second year of beets. This did not occur in the other rotations. The fact that percentages of sucrose were almost identical for the three treatments—manure only, manure and fertilizer, and fertilizer only—in the first crop year as well as the second crop year established that in this experiment the application of manure had no depressive effect on percentage of sucrose. It appeared that the alfalfa, even though separated by a crop of wheat, had the effect of significantly lowering the percentage of sucrose of the beet crop in comparison with the cereal rotation. This deleterious influence was still in evidence in the second crop of beets. There is also some suggestion that sweet clover has a similar effect in a reduced degree, since the percentages of sucrose and coefficients of apparent purity of beets grown on the sweet clover rotation are consistently midway between the comparable values for the 8-year alfalfa rotation and the 4-year cereal rotation.

It has been calculated by the use of prepared tables (*1*, *2*) that the total of all of the crops grown on the manured and fertilized plots of the 4-year rotation during two cycles consumed more phosphorus than the total of all crops grown on the comparable plots of the 8-year rotation. The calculated consumption per acre of P_2O_5 and the amount added in manure and fertilizer, disregarding that which remains in the cereal stubble (less than 2 pounds per acre), was as follows:

	Phosphate (P_2O_5) consumed	Phosphate (P_2O_5) added
8-year rotation	304 pounds	236 pounds
4-year rotation (2 cycles)	368 pounds	372 pounds

A superficial appraisal might suggest that the gradual depletion of the phosphorus by the 8-year rotation was the cause of the lower sucrose percentage. However, this explanation is not tenable unless it is conceded that a mild phosphorus deficiency is first expressed by a depression in sucrose percentage rather than by a depression in yield of roots, since the tons of beets per acre in the two rotations are quite comparable. The usually accepted contention (*3*) that sugar beets give a poorer performance after alfalfa than many other crops because the alfalfa has depleted the readily available P_2O_5 and left the remaining phosphorus in less soluble compounds, useable by oats, potatoes, etc. but not sugar beets, does not provide an explanation for the same reason.

Percentage of Sucrose as Affected by Nitrogen.—According to calculations (*1, 2*) 45 percent of the total amount of nitrogen consumed by the crops in the 8-year rotation and 43 percent of the consumption in the 4-year rotation has been returned in the form of manure. Hence it does not appear that there is sufficient difference in the nitrogen supply to constitute a full explanation of the difference in sucrose percentages. Undoubtedly on some of the plots the balance between nitrogen and phosphorus is so disturbed as to affect normal physiologic processes in the beet seriously.

Future plans include increased attention to chemical analyses of soils from these plots, and these analyses may provide helpful information toward the explanation of the significant differences in sucrose percentages.

Coefficient of Apparent Purity.—The coefficients of apparent purity showed a rather narrow variation, being affected significantly only by wide differences in available nutrient such as occurred in comparisons between the check plots and the fertilized plots or between the alfalfa rotation and the cereal rotation. This is in accordance with usual results in Alberta where even extensive variety tests frequently fail to display significant differences in coefficients of apparent purity.

Incidental Consideration

Potassic Fertilizer.—No benefit in sugar beet yields or percentages of sucrose has ever been noted from the addition of potash in the dozens of tests conducted in this area. There were no indications that any potash deficiency existed under conditions of this experiment.

Value of Farm Manure.—The value of the increases in the production of all crops in the rotation due to the application of barnyard manure in addition to phosphatic fertilizers has been calculated (*4*) and, based on 1945 prices, these increases in yield have shown the fol-

lowing money value per ton of manure applied for each of the three rotations:

Rotation	Value of each ton of barnyard manure applied
8-year rotation	$5.50
4-year cereal rotation	7.17
4-year green manure rotation	5.35

Summary

Ten years' results of yields, percentages of sucrose and coefficients of apparent purity of sugar beets grown under three rotational systems with addition of barnyard manure, phosphatic fertilizer, and green manure are presented.

The addition of barnyard manure brought about substantial increases in yield in all rotations and did not depress percentages of sucrose. The value of farm manure was in excess of $5 per ton in all rotations.

The application of phosphatic fertilizer in addition to manure seems justified on the basis of long-term policy and in this experiment produced increased yields which, however, were not significant.

Phosphatic fertilizer produced significantly higher tonnages in all rotations in the absence of manure but failed to maintain better than mediocre yields.

Evidence is presented which suggests considerable divergence from the usual behaviour of percentage of sucrose as related to yield. It is suggested that these differences may be ascribed to climate.

When neither manure nor phosphate fertilizer was added, the yields of roots and percentages of sucrose were disappointingly low and the young plants displayed marked susceptibility to seedling diseases and insect injury.

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Sugar Beets in Seven Michigan Systems of Crop Rotation[1]

R. L. Cook, C. E. Millar, and L. S. Robertson[2]

At a meeting of the sugar beet research committee, composed of representatives of beet sugar companies, the Farmers and Manufacturers Beet Sugar Association, and the Michigan Experiment Station, held at Michigan State College in 1939, attention became centered on the lack of experimental results pertaining to crop rotation and sequence. Such questions as "What crop should sugar beets follow in the rotation?", "Are legumes essential in the sugar beet rotation, and if so, what legume is most desirable?", and "What proportion of the rotation period should be allotted to the production of soil building legumes?" could not be definitely answered because of a lack of experimental evidence. To obtain such evidence the Ferden rotation and crop sequence experiment was started in the spring of 1940.

It is the object of this paper to explain the field lay-out and to present in full detail the results obtained with sugar beets. Other crop results are considered in so far as it is believed they might appreciably affect the over all program of the sugar beet farmer. Results of 1940 are not considered because it required that year to get the rotations started. There are also some errors in the 1941 results arising from getting the rotations under way. Not until 1942 did beets actually follow 2 years of alfalfa, and it was in 1942 that sugar beets in rotation 7 were first grown on land where sweetclover had been plowed under.

Field Layout and Plans

This experiment is being conducted on the Ferden farm in Saginaw County, 4 miles south of Chesaning. The soil contains from 25 to 28 per cent clay and 50 to 58 per cent stand. It is classified as Brookston sandy clay loam. The field is tiled but the structure is such that it drains rather slowly. There is a very gentle slope which allows some surface drainage.

Seven 5-year rotations are being studied. They are as follows:

1. Barley, alfalfa, alfalfa, corn, sugar beets.

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[2]Assistant Professor, Head of Department, and Assistant Professor, respectively. The authors express their thanks to the Farmers and Manufacturers Beets Sugar Association for making this study possible through financial assistance and to R. W. Bell of the Farm Crops Section of the Michigan Experiment Station for advice and assistance during the course of the work and for the presentation of the paper.

2. Barley, alfalfa, alfalfa, sugar beets, corn.
3. Barley, alfalfa, alfalfa, beans, sugar beets.
4. Barley, oats, alfalfa, corn, sugar beets.
5. Barley, oats, clover-timothy, corn, sugar beets.
6. Barley, beans, wheat, corn, sugar beets.
7. Barley, sweetclover, beans, wheat, sweet clover, corn, sugar beets. The sweetclover is seeded with barley and is plowed under the next spring for beans and is seeded in the spring on wheat to be plowed under the next spring for corn.

The plots are arranged in a split plot randomized block design. Treatments are replicated four times and all crops appear each year. Barley and sugar beets occur in all rotations. Corn appears in all but one of the rotations.

The field outline for block 1 is shown in figure 1. Each individual crop plot is 28 by 90 feet. The rotations were arranged at random in each block, with each rotation occupying five plots in each of the four blocks. The five plots provide for each of the five crops in the rotation, except, of course, that in rotations 1, 2, and 3 alfalfa occupies two plots out of the five. There are 140 plots in the entire experiment, 5 by 4 for each rotation, with 7 rotations. Each plot is then further divided into two 14 by 90 feet sub-plots. One sub-plot receives 2-16-8 fertilizer at the rate of 1,000 pounds per acre in 5 years while the other receives 400 pounds of the same fertilizer during the rotation period. In both cases one-half the fertilizer is applied for sugar beets and the other one-half for grain, all for barley in rotations 1, 2, and 3 and divided between the two grain crops in the other rotations. When the experiment was started, a flip of a coin determined which sub-plot was to receive the high fertilizer treatment.

To facilitate tractor and team work on the plots, it was decided at the outset that crops would not be placed entirely at random in the five plots within a rotation but would be grouped as much as possible so all of one series (A, B, C, D, or E) would grow a common crop within each block. Thus it was decided, by chance, that in block 1 barley should come in series B in all rotations (see figure 1) and that corn should come in series A and sugar beets in series C. Of course in rotation 2 the position of corn and sugar beets had to be reversed and in rotation 3 beans replaced corn. This variation offered no difficulty, however, because the land for all three crops can be fitted at the same time. With this arrangement, the plowing and fitting of three series in each block can be across the plots with all seven plots being worked simultaneously.

The other two crops in each rotation were placed, in the order of occurrence, in the other two series, D and E in figure 1. Because these other crops vary in the different rotations, it is necessary to work the plots individually.

Figure 1.—Field outline of block 1 of the Ferden rotation experiment showing the crops as they occurred on each plot during the 5 years under discussion.

N

Series E 90' →

28' ↔

28'

	Series A	Series B	Series C	Series D	Series E
45	Sugar beets	Barley	Corn	Alfalfa	Alfalfa
41 H	Corn	Alfalfa	Barley	Sugar beets	Alfalfa
42—	Barley 2	Alfalfa	Alfalfa	Corn	Sugar beets
43 L	Alfalfa	Sugar beets	Alfalfa	Barley	Corn
44	Alfalfa	Corn	Sugar beets	Alfalfa	Barley
45	Corn 7	Barley (sw cl)	Sugar beets	Wheat (sw cl)	Beans
41 H	Sugar beets	Beans	Barley (sw cl)	Corn	Wheat (sw cl)
42—	Barley (sw cl)	Wheat (sw cl)	Beans	Sugar beets	Corn
43 L	Beans	Corn	Wheat (sw cl)	Barley (sw cl)	Sugar beets
44	Wheat (sw cl)	Sugar beets	Corn	Beans	Barley (sw cl)
45	Corn	Barley	Sugar beets	Alfalfa	Oats
41 L	Sugar Beets	Oats	Barley	Corn	Alfalfa
42—	Barley	Alfalfa	Oats	Sugar beets	Corn
43 H	Oats 4	Corn	Alfalfa	Barley	Sugar beets
44	Alfalfa	Sugar beets	Corn	Oats	Barley
45	Corn	Barley	Sugar beets	Wheat	Beans
41 L	Sugar beets	Beans	Barley	Corn	Wheat
42—	Barley 6	Wheat	Beans	Sugar beets	Corn
43 H	Beans	Corn	Wheat	Barley	Sugar beets
44	Wheat	Sugar beets	Corn	Beans	Barley
45	Corn 5	Barley	Sugar beets	Clover-timothy	Oats
41 H	Sugar beets	Oats	Barley	Corn	Clover-timothy
42—	Barley	Clover-timothy	Oats	Sugar beets	Corn
42 L	Oats	Corn	Clover-timothy	Barley	Sugar beets
44	Clover-timothy	Sugar beets	Corn	Oats	Barley
45	Corn	Barley	Sugar beets	Alfalfa	Alfalfa
41 H	Sugar beets	Alfalfa	Barley	Corn	Alfalfa
42—	Barley	Alfalfa	Alfalfa	Sugar beets	Corn
43 L	Alfalfa 1	Corn	Alfalfa	Barley	Sugar beets
44	Alfalfa	Sugar beets	Corn	Alfalfa	Barley
45	Beans	Barley	Sugar beets	Alfalfa	Alfalfa
41 L	Sugar beets	Alfalfa	Barley	Beans	Alfalfa
42—	Barley	Alfalfa	Alfalfa	Sugar beets	Beans
43 H	Alfalfa 3	Beans	Alfalfa	Barley	Sugar beets
44	Alfalfa	Sugar beets	Beans	Alfalfa	Barley

Notes—"H" and "L" refer to high (1,000 pounds in 5 years) and low (400 pounds in 5 years) application of 22-16-8 fertilizer, respectively. The numerals in column A are rotation numbers corresponding with those given in the text. All plots are 90 feet east and west and 28 feet north and south. Alleys are 28 feet wide.

The use of manure and the disposition of crop residues are regulated according to the systems of farming which might be practiced with the different rotations. In rotations 1, 2, and 3, manure at the rate of 10 tons per acre is applied for corn or beans. In rotations like 4 and 5, with only 20 per cent of the land in hay production,

the farmer could not feed so many cattle so the manure application is 7 tons per acre. No manure is applied in rotations 6 and 7 because under such farming systems livestock would not be raised.

Corn stover is left on all the plots. Grain and bean straw and sugar beet tops are returned to the plots in rotations 6 and 7.

Barley in rotations 1, 2, and 3 and oats in rotation 4 serve as nurse crops for alfalfa. A red clover and timothy mixture is seeded with oats in rotation 5. Sweetclover is seeded with both grain crops in rotation 7 and is plowed under for beans and corn.

Plowing has been done in the spring and in only one direction. Thus dead and back furrows have been avoided. Oats and wheat have been planted after barley and beans, respectively, without plowing. All other plots have been plowed for each crop. Normal tillage methods have been followed. The 14-foot width of the sub-plots is right for one round of a grain drill (11 disk), four rows of corn, six of sugar beets, and six of beans.

With some variations because of seasonal and other unavoidable circumstances the harvest areas have been the entire plot in the case of grain, the center two rows of corn, and the center four rows of sugar beets and beans.

Experimental Results

The sugar beet yields obtained in this experiment are shown year by year in table 1. The results have varied markedly with seasonal conditions and they illustrate very nicely the need for many years results before definite conclusions may be drawn. There are, however, some noticeable trends already showing up.

The year 1941 was very good for sugar beets on this farm. The mechanical condition of the soil was good at planting time and weather was favorable throughout the season. Yields were high on all plots and were significantly higher on the plots in rotation 2 than on any other plots. The statistical analysis of the results showed that it required 2.75 tons of beets for a significant difference that year so there were no differences caused by rotation except that caused by rotation 2, where beets followed alfalfa.

During the late summer and fall the beets on rotation 2 looked much better than on any other plots. The tops were larger and of a much darker green. Green tissue tests made October 7 on the leaf petioles showed those on rotation 2 to be very high in nitrate nitrogen, while blank tests were obtained on all other plots. The correlation between color and test was very consistent. Apparently the beets were taking nitrogen from the decomposed alfalfa.

Table 1.—The effect of rotation at two fertility levels on the yields of sugar beets over a 5-year period.

	Tons per acre						
Rotation	1941	1942	1943	1944	1945	5-year mean	Rotation 5-year mean
1H	15.20	11.20	5.90	12.85	6.65	10.34	9.51
1L	14.73	8.98	4.81	10.88	3.78	8.68	
2H	20.80	12.30	4.23	12.73	4.34	10.88	10.02
2L	19.68	10.48	3.00	11.28	1.37	9.16	
3H	16.78	10.78	6.24	13.28	7.12	10.24	9.63
3L	15.60	8.70	5.83	10.73	4.12	9.02	
4H	16.50	11.30	5.67	11.68	7.07	10.45	9.52
4L	15.63	9.53	4.11	9.48	4.22	8.59	
5H	16.43	10.33	5.25	11.88	6.29	10.04	9.32
5L	15.40	8.75	4.60	10.45	3.80	8.60	
6H	16.13	9.85	4.82	10.85	6.53	9.64	8.79
6L	15.48	8.40	3.43	8.38	3.98	7.93	
7H	16.13	11.78	3.98	11.80	6.72	10.08	9.30
7L	15.70	10.53	3.62	9.55	4.05	8.69	
Diff. req. for sig. between rotations, Average of H and L	2.75	2.37	1.41	1.42	1.16	0.81	0.81
Diff. req. for sig. between levels in any one rotation	1.06	1.28	1.09	1.62	1.13	0.53	0.53

It seems desirable at this point to mention some supporting work done that same season on a similar soil in Tuscola county. The experiment is one designed to compare the effects of stable manure and sweetclover on various crops. The crop in 1941 was sugar beets. Tissue tests made on the green leaf petioles on September 19 showed without exception that beets growing where sweetclover had been plowed under that spring were well supplied with nitrate nitrogen. Where sweetclover had not been plowed under, the plants tested very low. Beets growing on manured plots gave intermediate tests. Apparently the beets were obtaining nitrogen from the decomposed sweetclover residues.

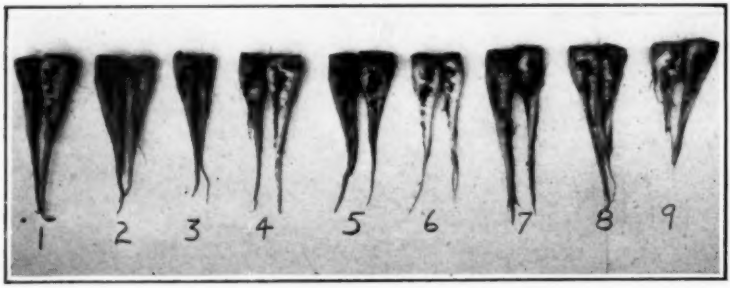

Figure 2.—Sugar beets grown in the greenhouse, comparing alfalfa with ammonium nitrate as a source of nitrogen.

1. No fertilizer—26,000 pounds green alfalfa per acre.
2. 2-16-8, 1,000 pounds—green alfalfa 26,000 pounds per acre.
3. 2-16-8, 1,000 pounds per acre.
4. 2-16-8, 1,000 pounds—NH_4NO_3, 900 pounds per acre.
5. 2-16-8, 1,000 pounds—NH_4NO_3, 600 pounds per acre.
6. 2-16-8, 1,000 pounds—NH_4NO_3, 300 pounds per acre.
7. 2-16-8, 1,000 pounds—NH_4NO_3, 600 pounds per acre in two applications of 300 pounds each.
8. 2-16-8, 1,000 pounds—NH_4NO_3, 900 pounds per acre in three applications of 300 pounds each.
9. 2-16-8, 1,900 pounds—NH_4NO_3, 900 pounds per acre in three applications of 300 pounds each.

Sugar beets require large quantities of nitrogen which may be very largely furnished by the nitrogen released from decomposing alfalfa. This has been shown by experiments performed in the greenhouse. Figure 2 shows the results obtained in an experiment performed in 2-gallon pots of soil taken from the Ferden farm. Each pair of beets represents the average of eight beets grown in four pots. The treatments are listed in the caption under figure 2. All treatments except No. 1 included 1,000 pounds per acre of 2-16-8 fertilizer. Treatments 1 and 2 included 106 grams of green chopped alfalfa per pot. This was considered to be about twice the weight, on an area basis, of an average crop of alfalfa in the field. Treatments 4 through 9 included NH_4NO_3 in different amounts in addition to the 2-16-8 fertilizer. Treatment 3 supplied only the 2-16-8 fertilizer at the rate of 1,000 pounds per acre. That it was insufficient is shown by the small size of the beets. Treatment 2 was just about equal to number 4. In other words 13 tons of green alfalfa, containing about 75 per cent water, had an effect about equal on the growth of the beets to 900 pounds of NH_4NO_3.

There are some indications that green manure, sweetclover, alfalfa, or grass is even better than stable manure in furnishing nitrogen for young sugar beet plants. This was shown on the Horst farm where sweetclover green manure proved better than manure and has been

shown to be true in pot cultures in the greenhouse. A comparison between alfalfa, manure, and grass is shown in figure 3. These materials were incorporated with soil from the Ferden plots at the rate of 10 tons fresh material per acre. The manure was fresh horse manure taken from a stable. The alfalfa was in the early blossom stage and the grass was lawn clippings. The beets growing on the pots which received manure alone, fertilizer alone, or both manure and fertilizer were very light green in color. They showed very pronounced signs of nitrogen starvation. The beets growing where grass or alfalfa had been mixed in the soil were larger and were very dark green, not deficient in nitrogen. In figure 3, the second pot from the left and the last one at the right show what a difference in growth resulted from the alfalfa green manure.

The results obtained in 1942 were quite similar to those of 1941. Again as shown in table 1, the highest yields were obtained on rotation 2, where beets followed alfalfa. The differences, however, were not as great as in 1941. The analysis showed that a difference of 2.37 tons was required before one could be sure the difference was not due to chance. The average yield of the high and low fertility plots in rotation 2 was 11.39 tons and in rotation 6, 9.13 tons or a difference of 2.26 tons, just slightly less than the value necessary to indicate significance.

In 1942, as in 1941, the color of the leaves in the fall and tests made on the green eptioles indicated that the beets on rotation 2 were getting sufficient nitrogen while those on all other rotations were deficient in nitrogen.

As a check on this alfalfa-nitrogen relationship a tour of the principal sugar beet counties was made on August 21-22, 1942. Stops were made wherever beets looked unusually green and healthy or unusually yellow. Tissue tests were made to confirm the fact that the dark green or yellow color was due to the presence or lack of sufficient

Figure 3.—Sugar beets grown on Brookston sandy clay loam from the Ferden plots. Treated as indicated. The 2-16-8 was applied at the rate of 1,000 pounds per acre and the grass, manure, and alfalfa at the rate of 10 tons fresh material in each case.

nitrogen. Invariably it was found that the beets having the best color and highest nitrate content were those which followed alfalfa or which were only 1 year away from an alfalfa crop. The most yellow field observed on that tour was on good soil where oats had been combined the year before. The oats had been a good crop and the straw was plowed under for the beets. The farmer could not remember that alfalfa had ever been grown on the field.

By analyzing the results from 1941 and 1942 together, it was possible to take out the variance due to years and the interaction variance between rotations and years. The result showed that rotations had caused highly significant differences in yield.

The season of 1943 was very poor for sugar beets on the Ferden farm. The spring was very wet and the soil on the plots was badly puddled when the beets were planted about a month later than is considered seasonal. The plants developed slowly and yields were about one-half as large as in the 1942 season.

Weather conditions during 1945 were vary similar to those during 1943. The two seasons differed in that in 1945 the planting date was much earlier and the soil at planting time was in fairly good condition. Rainfall immediately after planting, however, and for most of the growing season, was far above normal. It is safe to conclude that aeration was poor in that soil during much of the growing season.

A comparison now of the yields obtained during the 2 years 1943 and 1945, table 1, shows much in common. During both years rotation 2 slipped badly, producing yields lower than did any other rotation. In 1945 the average of the two yields was 2.86 tons, with the other six rotations yielding, as an average, from 5.05 to 5.65 tons. The difference is highly significant.

In 1944, another good season, legumes in the rotation caused significant increases in sugar beet yields. Beets in rotation 6 yielded significantly less than did those in rotations 1, 2, 3, and 5. Apparently better results were obtained from 2 years of alfalfa and from clover and timothy than from 1 year of alfalfa or from sweetclover. The beets in rotation 2, however, did not yield more than did those in rotations 1 and 3.

The variance caused by the interaction of rotations and years was highly significant when the first 3 years results were combined. Significance due to rotations, however, disappeared. This was because the behavior of beets in rotation 2 was exactly the reverse of what it was during the first 2 years. When the results for 1944 were combined with those for the first 3 years, the analysis showed that significant differences between rotations again resulted. Considering the 4-year averages of both high and low fertility plots, the beets

in rotation 2 yielded significantly more than did those in all other rotations except No. 3. The difference in yield between plots in rotations 2 and 3 was not significant. The average yield obtained from rotation 6, where there is no legume, was lower than from all other rotations but the differences were significant only in the case of 6 as compared to 2 or 3.

When the results for the 5 years were combined, some definite trends in the mean yields were apparent, although the statistical analysis shows that the differences are not large enough to be significant. It is seen in the last column in table 1 that when the yields from the high and low fertility plots are averaged the yield from rotation 2 is 1.23 tons higher than that from rotation 6, where no soil building legume has been grown. In fact the yield from rotation 2 is still above all other yields despite 2 adverse years, 1943 and 1945, for that rotation. It is interesting that the average yield from rotation 4 where there is only 1 year of alfalfa, is almost identical to that from rotation 1, with 2 years of alfalfa.

It is also interesting that whereas the yields from rotation 3, where beans replace corn, were below those from rotation 1 during the first 2 years the reverse was true during the last 3 years, and the 5-year average is slightly in favor of rotation 3. From the 5-year average, the effect of sweetclover seems about equal to that of red clover and slightly inferior to that of alfalfa.

The question arises, "Why did the yields of beets in rotation 2 fall so low during such years as 1943 and 1945, seasons of unusually high spring and early summer rainfall?" With the information at hand it is impossible to answer this question. The Ferden soil puddles easily if worked while too wet or if it is saturated for any considerable period. Under the poorly aerated conditions which exist during such periods, it is possible that some type of decomposition injurious to sugar beets may take place where the fresh alfalfa has recently been turned under. Further investigations are necessary, however, before such a conclusion can be definitely drawn.

Stand has been a problem in rotation 2 throughout the experiment. Each year the stands have been thinner than in any other rotation. The greater yields obtained on plots in that rotation during 1941 and 1942 were inspite of relatively poor stands. It is believed that the poor stands have been due to the mechanical difficulties of fitting a seed bed after alfalfa rather than to the effect of the alfalfa on disease. The plots have been relatively free of black root.

Levels of Fertility

Sugar beets are very responsive to commercial fertilizer. This has been shown by many experiments performed on a number of soil types in several of the principal sugar beet counties. At the beginning

of the Ferden experiment it was thought that the different cropping systems might have a different effect on sugar beets under different levels of plant food availability. Accordingly each plot was divided into two sub-plots, one to receive fertilizer at the rate of 400 pounds in 5 years and the other to receive 1,000 pounds during the same period.

Sugar beet yields have been significantly higher every year on the side of the plot which received the heavier application of fertilizer. The statistical analysis showed that after the first year a significant interaction existed between years and levels of fertilizer which continued through the fifth year and in the grouping of 5 years. This means that the beets did not respond the same each year to the two different levels of fertilizer. For instance the differences in yield due to the increased amount of fertilizer were larger in 1942 than in 1941 and were largest in 1945..

It was thought at the beginning of the experiment that in some cropping systems sugar beets might need more fertilizer than in others. In that case the differences between the yields resulting from the 1,000 pound application and the 400 pound application (one-half on the beets in each case) would have been greater in some rotations than in others. This was not true as was shown in the statistical analysis by a non-significant interaction between levels and rotations. Apparently the response of the beets to the fertilizer was the same in all the seven rotations.

Sucrose Content

A discussion of any agronomic practices pertaining to sugar beets would not be complete without a consideration of sucrose content. Except for the year 1943, the sucrose content of the beets on all plots was determined each year at harvest time. During 1941 and 1942 the beets grown on rotation 2 were lower in percentage of sucrose than were those from any other rotation. As shown by the data presented in table 2 the difference in 1941 was highly significant but was not significant in 1942. It seems doubtful if this higher sucrose content was actually due to the alfalfa which preceded the sugar beets, because the relationship did not hold in 1944 and 1945. In 1941 and 1942 the yields were greater on the plots in rotation 2. This was in spite of poorer stands. That means that the average weight of beets was greater on the rotation 2 plots. It is generally recognized that larger beets are lower in sucrose than are smaller beets.

Table 2.—The effect of rotation on the sucrose content of sugar beets.

Rotation	Percent sucrose			
	1941	1942	1944	1945
1	16.8	16.3	17.2	16.7
2	15.0	15.5	17.2	16.6
3	17.0	16.1	17.5	16.3
4	16.8	16.1	17.2	16.9
5	17.1	15.9	17.2	17.0
6	16.8	16.7	17.5	17.0
7	16.7	16.3	18.0	17.5
Significance (rotations)	**	....	....	*
Difference required for significance between rotations	0.7	0.9	1.1	0.2

In 1944 and 1945 the highest sucrose percentages were obtained on beets grown in rotation 7, where sweetclover was turned under as green manure in the spring of 1943 and 1944 respectively. The difference was significant in 1945. It was also found in 1945 that the percentages of sucrose were lower in beets grown in the three rotations which include 2 years of alfalfa than in the other four rotations. This would again indicate that possibly alfalfa does tend to lower sucrose percentages.

The sucrose content of the sugar beets on the Ferden plots was not significantly different on the plots which received the larger as compared to the smaller applications of fertilizer.

Other Crops

Michigan sugar beet growers are interested in several other cash crops. Most important among these are corn, white beans, and wheat. It is necessary then that these crops be considered before deciding on a suitable rotation for sugar beets. It would not of course be wise to sacrifice, by carrying out some practice favorable to sugar beets, more on other crops than was gained on the beets.

Corn

Six of the rotations in this study include corn. The results presented in table 3 show that corn yields have been very significantly affected by the legumes in the rotation. Considering the results year by year the data show that in 1942, 1944, and 1945 the differences in yield caused by rotations were highly significant. This is also true of the 5-year averages. The highest average yields were obtained where alfalfa occurred in the rotation, while the lowest yields occurred in rotation 6 where no soil building legume is grown. It is interesting to note that 1 year of alfalfa in the rotation (rotation 4) was as good

Table 3.—The effect of rotation at two levels of fertilizer application on the yearly and 5-year average yields of corn.

	Bushels per acre						
Rotation	1941	1942	1943	1944	1945	Mean	Rotation Mean
1H	45.7	72.8	30.5	35.2	39.9	44.8	44.7
1L	47.6	71.4	27.5	36.8	39.9	44.6	
2H	35.4	70.0	25.6	32.5	34.8	39.7	39.1
2L	35.6	63.8	26.9	31.3	34.5	38.4	
4H	47.9	69.2	30.2	34.6	47.3	45.8	45.5
4L	48.3	68.9	29.9	36.3	42.1	45.1	
5H	46.6	66.4	22.9	33.1	34.6	40.7	42.3
5L	47.0	69.3	22.8	36.2	43.7	43.8	
6H	45.5	47.0	20.1	28.5	27.7	33.8	33.1
6L	41.4	51.2	17.3	27.6	24.4	32.4	
7H	45.5	70.4	22.5	29.0	34.9	40.5	39.5
7L	45.1	65.0	23.6	29.0	29.4	38.4	
Significance (rotations)		**		**	**		**
Difference required for significance between rotations	11.6	10.8	7.6	3.6	4.6		3.5

as 2. In fact the yield of corn obtained in rotation 4 averaged slightly higher than that obtained in rotation 2 where alfalfa has been grown for 2 years out of 5. In this respect the corn and sugar beet yields agree.

Compare now the corn yields from rotation 2 with those from rotation 1, where exactly the same crops are grown but where the order of corn and sugar beets are reversed. Where corn has followed sugar beets the average yield for 5 years has been significantly less than where corn has followed alfalfa. In other words what has been gained by growing sugar beets directly after alfalfa has been at least partly lost on the corn crop.

Judging from the results obtained with corn in this experiment, sweetclover is greatly inferior to alfalfa as a soil building crop. The average yield of 39.5 bushels obtained in rotation 7 is significantly less than that obtained from either of the alfalfa rotations where corn

immediately followed the alfalfa crop. That sweetclover was beneficial, however, is shown by the fact that corn in rotation 7 significantly outyielded corn in rotation 6, where no legume is grown.

Red clover and timothy seemed slightly inferior to alfalfa but the difference between the yields of corn caused by the two soil building crops was too small to be significant.

White Beans and Wheat

White beans are grown in the rotation with sugar beets on many Michigan farms. As has already been shown sugar beets do well after beans. Since beans are a rather high value cash crop, it is important that one consider the effect of other crops on bean yields. The crop is included in rotations 3, 6, and 7 so it is possible to determine the effect of two soil building legumes, alfalfa and sweetclover.

As shown by the results presented in table 4, the highest yields have occurred in rotation 3, where beans have followed alfalfa. The average yield for the rotation, averaging the yields from the high and low fertilized plots, over a period of 5 years is 16.5 bushels per acre as compared to a yield of 13.7 bushels where no soil building legume has been grown. In rotation 7 the crops grown are exactly the same as in rotation 6 except that sweetclover is grown twice in the rotation for green manure. It is seeded in barley and is plowed under the following spring for beans. The data show that the effect of the sweetclover on the beans has been about half as great as the effect of alfalfa, an average increase of 1.5 bushels of beans for the sweetclover green manure as compared to an increase of 2.8 bushels as a result of the alfalfa in rotation 3.

Table 4.—The effect of rotation at two levels of fertilizer application on the yearly and 5-year average yields of white beans.

	Bushels per acre						
Rotation	1941	1942	1943	1944	1945	Mean	Rotation Mean
3H	22.0	20.6	16.5	4.9	19.0	16.6	16.5
3L	20.0	20.1	17.3	5.3	18.8	16.3	
6H	22.0	13.7	13.6	6.5	14.8	14.1	13.7
6L	20.0	13.6	11.5	5.6	15.1	13.2	
7H	24.5	15.0	14.2	4.1	16.3	14.8	15.2
7L	26.6	16.7	12.2	6.1	16.5	15.6	

Wheat follows beans in rotation 6 and 7. That the sweetclover which was plowed under for beans in rotation 7 increased the yield of wheat is shown by the data recorded in table 5. The average yield increase over the 5-year period was 3.6 bushels per acre. Thus it is seen that from one sweetclover manure crop is obtained 1.5 bushels of beans and 3.6 bushels of wheat. The money spent for 10 pounds of sweetclover seed was indeed very well invested.

Table 5.—The effect of rotation at two levels of fertilizer application on the yearly and 5-year average yields of wheat.

	Bushels per acre						
Rotation	1941	1942	1943	1944	1945	Mean	Rotation Mean
6H	28.0	30.1	18.8	29.4	33.4	28.0	27.0
6L	26.6	26.7	16.7	25.3	34.9	26.0	
7H	30.7	42.5	19.2	30.9	35.5	31.8	30.6
7L	27.5	38.8	19.3	26.7	34.3	29.3	

Levels of Fertility

Fertilizers were not applied directly for corn and beans. One might expect, however, some residual effect from fertilizer applied for the grain and sugar beet crops. The data reported in tables 3 and 4 show that such was not the case. The statistical analysis of the corn yields shows that the variance due to levels of fertilizer was very small. The 120 corn yields in all rotations, from the plots which received the heavy applications of fertilizer averaged 40.9 bushels per acre as compared to a yield of 40.4 bushels from the plots which received the lower quantity of fertilizer. The difference is within the range of experimental error.

Wheat has been fertilized directly at the time of planting. During the 3 years 1941, 1942, and 1944 the yields were definitely higher on the more heavily fertilized plots, but during the years 1943 and 1945 there was no increase in yield as a result of the larger application. In spite of this, however, the 5-year averages still show about 2 bushels of wheat in favor of the higher application. If the increase is really significant it was profitable as the extra 150 pounds of 2-16-8 fertilizer costs less than the value of 2 bushels of wheat.

Summary

A crop rotation and sequence experiment designed especially to determine the effects of other crops on sugar beets was started in 1940 on Brookston sandy clay loam on the Ferden farm in Saginaw County, Michigan. Seven rotations, all including sugar beets, are being studied. Plots are replicated four times, and all crops appear each year. The plots are arranged in a split-plot, randomized block

design with each rotation conducted at two fertility levels. The plot size and arrangement is such that all tillage, planting, and harvesting can be done with standard farm machinery.

During the 5 years 1941 to 1945 inclusive, some very interesting observations and yield results have been obtained from the sugar beets grown on the plots. During 2 of the 5 years the highest yields occurred in rotation 2, where beets follow alfalfa. In 1944 the yields of beets from rotation 2 were about equal to those from rotations 1 and 3, where beets follow corn and beans, respectively. Weather conditions during these 3 years were fairly good for beets in the Ferden area. During the other 2 years, 1943 and 1945, seasons of heavy spring and summer rainfall, yields were generally low and those from rotation 2 were lower than those from the rotations where beets followed corn or beans.

Considering the 5-year averages, the lowest yields have occurred in rotation 6, where no soil building legume has been grown. Alfalfa in the rotation has caused higher yields than has sweetclover. One year of alfalfa in a 5-year rotation has given as good results as 2 years. Red clover and sweetclover have proven to be about equal in their effects on sugar beet yields.

Sugar beet yields have been significantly higher where the fertilizer applications have been at the rate of 1,000 pounds in 5 years than where the rate of application has been 400 pounds. The response to the heavier fertilizer application has not varied among the different rotations but has varied from year to year.

Very significant differences have shown up in the yields of corn obtained in the different cropping systems. Where no soil building legume has been grown, corn yields have been about 12 bushels below those obtained where the rotation included alfalfa and where corn followed directly after the alfalfa. One year of alfalfa has been as good as 2 in the rotation.

Where sugar beets followed the alfalfa and corn followed the sugar beets, corn yields have been about 6 bushels below those obtained where corn followed the alfalfa immediately.

Red clover has been slightly inferior to alfalfa, in so far as effect on corn yields is concerned, and sweetclover has been the poorest of the three legumes.

Bean yields have been increased by soil building legumes in the rotation. Alfalfa has given better results than sweetclover.

Wheat yields have been increased by the plowing under of sweetclover green manure in the rotation.

The heavier applications of fertilizer have increased wheat yields, as compared to yields obtained from plots where the lesser quantity of fertilizer has been applied, but have not affected corn or bean yields.

Plant Analysis as a Guide in the Fertilization of Sugar Beets [1]

ALBERT ULRICH[2]

The need for better methods of determining the fertilizer requirements of sugar beets is emphasized whenever a fertilizer program is proposed for a field of beets. While soil analyses conducted either through chemical or biological means are helpful in estimating the concentrations of nutrients in the soil that are available to plants, they do not indicate what the crop is actually getting from the soil under the prevailing climatic conditions. In contrast to soil analysis, analyses of plant samples properly collected from the field will indicate what the plant is getting from the soil in relation to its environment. When the analytical values from the plant samples are compared with the critical levels for each nutrient, conclusions may be drawn with respect to the adequacy or inadequacy of the nutrients at the time of taking the sample. By collecting plant samples from the same field at regular intervals, the relative importance of the deficiency can be estimated from its duration and from the time of its occurence during the growing season. It is obvious that the longer the plant is deficient in a given nutrient, and the earlier in the growing season the deficiency takes place, the greater the chance of getting an increase in yield from adding the required nutrient to the soil.

In order to interpret the results of plant analysis, the values must be compared with the critical level for each nutrient as estimated from previous experimentation. For practical purposes the critical nutrient level may be defined as "that narrow range of concentrations in which the growth rate or yield first begins to decrease in comparison with plants at a higher nutrient level" (*3*)[3]. Thus, plants with nutrient concentrations well above the critical level are likely to be adequately supplied with nutrients at the time of collecting the samples, while plants with nutrient concentrations at or below the critical level are likely to be deficient in nutrients.

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[1]In conducting the surveys in 1943 through 1945, aid from many sources was obtained. Field men of the Spreckels, Holly, and American Crystal Sugar Companies and of the California Packing Corporation collected the leaf samples and supplied the crop and fertilizer data for each field sampled. Grants-in-aid for analytical assistance were received from the American Potash Institute, the Barrett Division of the Allied Chemical & Dye Corporation, California Fertilizer Association, Chilean Nitrate Sales Corporation, and National Fertilizer Association.

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[3]Italic numbers in parentheses refer to literature cited.

When plant samples are collected at regular intervals the analytical results may be helpful in at least three ways, first by disclosing nutrient deficiencies which may be corrected when detected early in the growing season; second by observing changes in the nutrient composition of the beets produced from additions of fertilizers or from changes in cropping practices, and third by indicating adjustments to be made in subsequent fertilizer and cropping practices on the field which has been sampled. In order to correct nutrient deficiencies arising during the current season, speed is essential, both in reporting the analytical results and in making the fertilizer applications in the field. However, as more experience is gained, emergency applications of fertilizers on beet fields should become less important and more emphasis placed upon maintaining a high level of soil fertility in relation to the nitrogen, phosphorus, and potassium requirements of sugar beets. By keeping a record of the nutrient status of each crop of beets, and if possible of all other crops grown on the field, the general trend in the fertility level of the field can be observed and changes in the cultural practices introduced in time to counteract decreases in fertility of the soil.

Procedure of Sampling

Success in the use of plant analysis as a means of determining the nutrient status of sugar beets depends largely upon the technique adopted in the sampling of beet plants. Preliminary studies in our laboratories (*2*) and by Brown (*1*) have indicated that the petiole of the youngest "mature" leaf reflects satisfactorily the nitrogen and phosphorus status of sugar beets. Recent studies have also indicated that the same part of the plant may be used for estimating the potassium status of sugar beets.

The procedure usually followed in collecting petiole samples (*4, 5*) is to divide a field into approximately four equal parts. A sample from each part is collected by walking across the planting rows and taking the petiole of the one leaf selected from each of the 30 to 40 locations uniformly spaced across the center of each quarter of the field. Thus, four samples are collected from each field for individual laboratory analysis. The petioles are then cut into sections of 2 to 5 millimeters in length. A representative sample of 50 or 100 grams of freshly sliced material is dried rapidly in an oven with air circulating at temperatures from 70° to 80° C. The dried plant material is ground in a Wiley mill to pass a 40-mesh sieve and stored in bottles until analyzed for nitrate, phosphate, and potassium. Samples collected every 2 to 4 weeks, starting shortly after thinning and ending at harvest time, are sufficient to show the trends in the nutrient status of sugar beets under field conditions.

Plant Nutrient Surveys

In 1943 and 1944 seventy fields of sugar beets located in the Monterey, San Benito, and Santa Clara counties and in the Sacramento and San Joaquin valleys were sampled at intervals of 3 to 5 weeks during the growing season (*4*, *5*). Each field in the survey was selected on the basis of its productivity. As a rule each field man in a given district sampled one field that was considered by him to be either average or above average and another field that was considered to be below average in productivity. In no case were fields selected that were suspected of being seriously affected by diseases or pests or by any other known factor, with the possible exception of a plant nutrient deficiency.

The analytical results obtained for the leaf samples from each field in the survey were compared with the critical levels for each nutrient which, expressed on the dry basis, are tentatively as follows: 1,000 p.p.m. of nitrate nitrogen for nitrogen, 1,000 p.p.m. of phosphate-phosphorus extracted by 2 percent acetic acid for phosphorus, and 2 percent total potassium for potassium. By making these comparisons for the 70 fields sampled during the 2-year period it was found that 70 percent of the fields were below the critical nitrogen level long enough to warrant experiments with nitrogen, 28 percent in the case of phosphorus, and 6 percent for potassium. When fields below the critical level for a short time only are included as being suitable for experimentation, the percentages would be 88 percent for nitrogen, 41 percent for phosphorus, and 14 percent for potassium. Whether or not the fields which were indicated as being deficient by plant analysis would actually respond to the fertilizers must, of course, be determined by experiments on these fields.

Demonstration Experiments

In order to evaluate the effectiveness of plant analysis as an aid in determining the fertilizer requirements of sugar beets, many field experiments or demonstration trials must be established in each sugar beet district. When conducting these experiments, nutrient content comparisons should be made between plants that are deficient and those in adjacent plots that have been fertilized adequately with the required nutrient. These comparisons should result in a satisfactory correlation between the nutrient content of the plant and yield response, providing that the fundamental concept of the critical nutrient level is valid. However, when making the comparisons between nutrient levels and yields, it should be noted at the beginning that there will be a number of instances in which the nutrient concentrations of the unfertilized beets will be at the critical level, and yet, after fertilization there will be no significant increases in yield even though

the nutrient concentrations of the beets have been increased above the critical level. In these instances the increases in yield will be relatively small and unless the design of the experiment is efficient they will not be detected.

Table 1.—Nitrate concentration below the critical level in sugar beet petitoles from the untreated demonstration plot on Salinas clay located near King City, Calif.*

		Plant analyses		
Sampled	Treatment**	NO_3 - N p.p.m.	Sol. PO_4 - P p.p.m.	K percent
June 28	None	300	2,600	7.52
	N	200	2,440	6.84
	2 N	1,100	2,600	7.94
July 25	None	280	1,690	7.16
	N	10,500	1,530	6.49
	2 N	12,800	1,700	6.51
August 25	None	20	1,610	6.87
	N	300	1,570	5.30
	2 N	1,470	1,580	5.30

*The leaf samples and yields were obtained by Mr. Harold Voth of the Spreckels Sugar Company.

** N=400— 500 pounds ammonium sulfate per acre.
2 N=800—1000 pounds ammonium sulfate per acre.

The fertilizers were applied June 17, and thereafter the field was irrigated on July 5 and August 3. The beets were harvested on November 21, 1944. The yields for the untreated, N, and 2 N plots were 12.2, 20.3, and 20.9 tons of beets per acre, respectively, while the corresponding sugar concentrations were 17.8, 17.3, and 17.1 percent.

During 1944 and 1945 a number of demonstration plots were established by the fieldmen of the Spreckels Sugar Company. Six trials were conducted, and in all cases the results were in accord with the leaf analyses that were made during the course of the experiment. The results of 3 of these trials are reported in tables 1 to 3. The data of tables 1 and 2 indicate that when beets from unfertilized plots have nitrogen concentrations well below the critical level, the addition of nitrogen increases the nitrate concentration of the beets considerably during part of the growing season. In the plots near King City, Calif., (table 1) the addition of nitrogen increased the yields from 12 tons per acre for the untreated plots to 20 tons per acre for the N treatment and to 21 tons per acre for the 2N treatment. At Grimes, Calif., (table 2) the yields were increased from 14.4 tons per acre to 16.7 tons per acre by the addition of 335 pounds of ammonium nitrate per acre. In contrast to the plots in which yield increases were obtained when the beets reached the critical nitrogen level, the results given in table 3 for a field of beets near Ryde, Calif., indicate that when the beets have nitrogen concentrations well above the critical level on all sampling dates, the addition of nitrogen fails to give a response. However, an inspection of the analyses for phosphorus and potassium of this field suggests that the beets were

Table 2.—Nitrate concentrations below the critical level in sugar beet petioles from the untreated demonstration plots on Sacramento clay located near Grimes, Calif.*

		Plant analyses		
Sampled	Treatment**	NO_3 - N p.p.m.	Sol. PO_4 - P p.p.m.	K percent
June 19	None West	3,940	1,050	3.91
	None East	5,100	990	3.68
	N West	4,310	640	4.25
	N East	4,200	880	4.40
July 2	None West	2,580	1,100	3.29
	None East	1,850	1,410	3.14
	N West	12,000	1,170	3.34
	N East	7,700	1,200	3.14
July 31	None West	490	1,370	2.77
	None East	250	1,700	2.97
	N West	2,700	1,180	2.39
	N East	4,880	1,560	2.51
Sept. 25	None West	0	575	2.35
	None West	8	850	2.66
	N West	25	652	0.88
	N East	210	927	1.24

*The leaf samples and yields were obtained by Mr. M. G. Raney of the Spreckels Sugar Company.

**N = 335 pounds ammonium nitrate per acre drilled into center of irrigation furrows on June 5, 1945. Thereafter the field was irrigated on June 19 after taking the first plant samples.

The average yields from the unfertilized and fertilized plots on October 17 were 14.4 and 16.7 tons of beets per acre, respectively, while the corresponding sugar concentrations were 18.9 and 19.0 percent.

deficient in phosphorus and possibly in potassium, and therefore phosphorus alone and in combination with potassium should have been tried on this field. After phosphorus is added, the changes in the nitrogen and potassium concentration of the beets should be followed carefully because the increased growth caused by the phosphorus application should draw more heavily on the nitrogen and potassium reserves of the soil.

Field History

The importance of keeping a record of the nutrient levels of crops grown on the same field is shown in tables 4 and 5 for beet leaves sampled in 1943 and again in 1945. Prior to leaf sampling the field had been in beets in 1942, barley in 1941, oats in 1940, and asparagus in 1939 and for many years preceding this date. No fertilizer was used on this field until 1942 when 400 pounds of 30-20-0 per acre was applied. In 1943 when plant samples were first collected, the beets were fertilized with 400 pounds of nitrate of soda per acre. The results of

Table 3.—Nitrate concentrations above the critical level in sugar beet petioles from the demonstration plots on Ryde clay loam located near Ryde, Calif.*

		Plant analyses		
Sampled	Treatment**	NO_3 - N p.p.m.	Sol. PO_4 - P p.p.m.	K percent
June 20	None	8,000	1,230	3.08
	N	11,000	1,080	3.02
July 18	None	8,100	840	2.17
	N	8,200	840	2.50
August 23	None	5,300	540	1.71
	N	5,500	740	2.01
September 28	None	7,600	520	1.69
	N	5,900	410	1.90

*The leaf samples and visual observations were taken by Mr. G. W. Zellinger of the Spreckels Sugar Company.

**200 pounds ammonium nitrate drilled into the soil on May 22. Thereafter the field was first irrigated on June 10. The average yield for the entire field on January 15, 1945, was 21.9 tons of beets per acre, while the sugar concentration was 11.5 percent.

All figures for the N treatment are averages from three sections of the field.

There was no visible response to the nitrogen application.

the leaf sampling for four sections of the field are given in table 4. The chemical analyses presented in the table indicate that the beets were primarily deficient in nitrogen, although at times they were somewhat low in phosphorus throughout the field.

In 1944 the field was planted to carrots, which were grown for seed, and during this period no fertilizer was applied. In 1945 the field was again planted to beets, and it received 480 pounds of nitrate of soda per acre on April 15 as a side dressing and 150 pounds of ammonium nitrate per acre applied through the sprinkling system on June 24. On each sampling date two samples were collected from Sections A and B and three at intervals from Section C. The analytical results from these sections are reported in table 5 as averages for each section. The chemical analyses of these samples indicate that the beets were well supplied with nitrogen throughout all the growing season and that phosphorus was low in mid-July, through August, and at the time of harvest in September. Therefore the use of phosphorus in addition to nitrogen should now be considered for this field, particularly when it is planted to sugar beets. Potassium was apparently adequate, as shown by the potassium analyses for the 2 years.

Table 4.—Plant nutrient status of sugar beets on Egbert muck located near Rio Vista, Calif., for 1943*

Sampled	Section	Plant analyses		
		NO_3 - N p.p.m.	Sol. PO_4 - P p.p.m.	K percent
June 7	A	5,400	1,190	6.42
	B	7,400	1,120	6.52
	C	8,200	980	6.23
	D	3,240	1,370	4.98
June 28	A	2,450	850	5.91
	B	1,500	893	5.77
	C	1,330	1,090	5.21
	D	1,130	1,160	4.30
July 26	A	720	670	6.19
	B	76	880	6.99
	C	182	900	6.09
	D	46	960	5.68
Sept. 9	A	99	670	6.90
	B	38	1,060	7.89
	C	38	1,230	6.68
	D	23	890	7.17
Oct. 4	A	30	830	6.73
	B	23	1,340	6.51
	C	15	1,620	6.10
	D	38	1,340	6.16

*The leaf samples were collected by Mr. L. A. Kloor of the Holly Sugar Company. On October 9, 1943, the field produced 17.1 tons of beets per acre with an average sugar concentration of 19.1 percent.

Table 5.—Plant nutrient status of sugar beets on Egbert muck located near Rio Vista, Calif., for 1945* (same field as in table 4).

Sampled	Section	Plant analyses		
		NO_3 - N p.p.m.	Sol. PO_4 - P p.p.m.	K percent
June 21	A	10,150	1,230	3.58
	B	11,800	1,100	3.86
July 5	A	7,000	1,070	3.73
	B	7,900	1,025	2.96
	C	7,000	1,000	2.81
Aug. 6	A	4,490	670	3.71
	B	7,600	700	3.59
	C	4,800	730	3.73
Aug. 22	A	1,620	610	5.59
	B	3,800	640	4.35
	C	2,770	800	5.14
Sept. 6	A	1,070	525	5.14
	B	1,300	510	5.37
	C	2,050	620	4.99

*The leaf samples were collected by Mr. J. W. Coover of the California Packing Corporation.
On September 11, 1945, the field produced 20.3 tons of beets per acre with an average sugar concentration of 15.5 percent.

Summary

Plant nutrient surveys of sugar beet fields were made by analyzing petioles of leaves collected from 70 fields in the Salinas, San Joaquin, and Sacramento Valleys of California during 1943 and 1944. Four samples were taken from each field three to five times during the growing season of each year. After the samples were dried at 70 to 80° C. analyses were made for nitrate, soluble phosphate, and potassium. The analytical values for each sample were expressed on the dry basis and were then compared with the critical values for each nutrient. The critical values are approximately 1,000 p.p.m. of nitrate nitrogen; 1,000 p.p.m. of phosphate-phosphorus, soluble in 2 percent acetic acid; and 2 percent total potassium.

Of the 70 fields sampled during the 2-year period 70 percent were below the critical level for a long enough time to warrant experiments with nitrogen, 28 percent with phosphorus, and 6 percent with potassium. When fields below the critical level for only a short time are included as being suitable for experimentation, the corresponding figures are 88 percent for nitrogen, 41 percent for phosphorus, and 14 percent for potassium.

The yields and growth responses observed in six fertilizer demonstration trials conducted during 1944 and 1945 were in accord with petiole analyses. The results of three of these trials are reported in this paper.

Plant samples taken at regular intervals from the same field planted to beets in 1943 and 1945 indicate that plant analysis may serve as a guide in adjusting the fertilizer program for the next crop of beets on the field.

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Sugar Beet Petiole Tests as a Measure Of Soil Fertility

Robert J. Brown[1]

The beet grower who owns his farm can maintain the fertility of the soil at a high point with no fear that money spent on surplus plant nutrients during one season will be lost. The tenant grower too often is in the position where the only certain returns he can see are in the current season. And therefore the tendency is merely to maintain such farms, at best, at the range of the dividing line between sufficiency and deficiency. The low level of the average beet yield indicates that a larger percentage of the farms are in this class. The growers in this class require that any fertilizer treatment produce an immediate response which repays for the treatment. Soil tests measure the available phosphate and potash with a satisfactory degree of accuracy, but give little useful information regarding nitrogen.

In the present discussion we have only slight interest in potash, since field trials on our soils, lowest in available potash, have not indicated a potash deficiency. Although soil tests measure the available phosphate with a high degree of accuracy, various factors, such as the variable requirement of the sugar beet for phosphate in different environments, make the interpretation of the results of the soil test unsatisfactory on a large percentage of soils. Too many soils fall in the doubtful classification. It appears logical that the plant itself which is the integration of all factors—soil nutrient status, climate, etc.—may be used to determine fertilization requirements. To be useful in the sugar beet crop it must be possible to gain the desired information sufficiently early in the season to permit of correction in the current crop.

Plant tissue tests are steadily becoming more popular as a measure of soil fertility. Investigators are not agreed as to which part of the plant should be tested, nor as to how tests should be made. One school favors tests on conducting tissue for non-assimilated plant nutrients. The other uses leaf tissue and analyzes for total content of those constituents. Various investigators have found that the sugar beet petiole is a good indicator of the supply of available nutrients, and the following presents results of petiole tests made in the Great Western Sugar Company area during recent years.

Petiole tests were made on cold water extracts of petiole matter ground in a mortar or food blender. All results are reported on the basis of parts per million of nitrate nitrogen and phosphate phos-

[1]Great Western Sugar Company research laboratory.

phorus on original petiole matter. The earlier samples consisted of 10 to 12 petioles taken from as many randomly selected beets. In 1942 an accurate sampling technique was developed and since that date larger samples have been used.

In 1940 the primary interest was in phosphate, and periodic soil and petiole tests were made on samples from six widely scattered fields.

Results of individual petiole tests were very erratic. Below are given the results of the average petiole tests on three samplings during June, July, and August, compared with beet yields.

Table 1.—Petiole tests for phosphate and beet yields, 1940.

Field No.	p.p.m. of P in petioles	Root yield Tons per acre
1	138	10.9
2	134	16.3
3	84	13.4
4	82	19.0
5	63	22.3
6	60	22.0

Soil and petiole tests showed excellent correlation. It is curious that yield varies inversely with the phosphate test. There was no visual evidence that nitrogen was a controlling factor in these yields.

In 1941 periodic petiole tests were made on 66 commercial beet fields in the Colorado and Nebraska area of the Great Western Sugar Company. Results were very erratic and in table 2 are given average results of tests on 46 fields sampled during July, August, and September, grouped according to beet yield.

Table 2.—Periodic petiole tests, 1941. Average of petiole tests during July, August, and September.

Yield group	+20 tons	17 to 20 tons	14 to 16.9 tons	11 to 13.9 tons	Less than 11 tons
No. of fields in group	7	11	14	6	8
	p.p.m.—N	p.p.m.—N	p.p.m.—N	p.p.m.—N	p.p.m.—N
July	379	494	682	307	443
August	666	325	807	226	574
September	212	122	236	30	112
	p.p.m.—P	p.p.m.—P	p.p.m.—P	p.p.m.—P	p.p.m.—P
July	144	110	109	98	116
August	96	88	52	56	92
September	63	54	47	38	44

Some may be inclined to discount the significance of group averages, especially in the low-yield groups, since reciprocal relations of N and P are often observed. This is most common in the high-yield groups, when high yield associated with very low nitrate test is often accompanied by high phosphate test, and vice versa. Among the 14 fields comprising the two low-yield groups, only 2 gave results indi-

cating that low phosphate was responsible for accumulation of nitrates and only 1 indicated that high phosphate accumulated as the result of low nitrates.

In 1942 petiole tests were made with the primary object of determining sampling requirements necessary to provide a petiole sample of known error limits. The results of this work were published in Soil Science, Vol. 56, p. 213 (Sept. 1943). Since that date the samples taken have consisted of a composite of single petioles from one of the group of youngest mature leaves from 72 to 75 randomly selected beets. This sample has an error limit of not over 20 percent at the 9 to 1 probability ratio. The 1942 work has little bearing on the present discussion, but it may be pointed out that the various fields sampled during this work showed almost complete loss of nitrates by the end of July.

Accurate samples were taken periodically from 10 fields in a single factory district in 1944. A summary of average results is given in table 3. The figures shown are averages of results from fields grouped according to yield. Figures on individual fields are of little value, and on averages of a small number of fields they are of doubtful value. Results from one field, far out of line, are not included in the averages.

Table 3.—Periodic petiole tests, 1944.

Yield group	+17 tons	17 to 10 tons	Minus 10 tons
Fields in group	2	4	3
	p.p.m.—N	p.p.m.—N	p.p.m.—N
July	669	434	253
August	300	343	105
September	226	189	33
	p.p.m.—P	p.p.m.—P	p.p.m.—P
July	93	87	101
August	89	91	90
September	54	55	36

One field which yielded 17.5 tons of beets showed practically no nitrates at any time during the season. The average phosphate test was 116 p.p.m.

The 1945 tests were made on five pairs of fields in five factory districts in Colorado and Nebraska, sampled periodically throughout the season. Each pair consisted of one fertile and one infertile field.

The average results of petiole tests on fields grouped according to yield are given in table 4.

Table 4.—Periodic petiole tests, 1945.

Yield group	+15 tons	15 to 10 tons	Minus 10 tons
Fields in group	3	4	3
	p.p.m.—N	p.p.m.—N	p.p.m.—N
July	683	986	846
August	195	296	356
September	135	190	169
	p.p.m.—P	p.p.m.—P	p.p.m.—P
July	85	108	60
August	84	94	56
September	78	79	40

Although the evidence as presented does not indicate it, 1941 and 1945 were years when nitrates held up generally high until late in the season, and 1942 and 1944 were seasons of early depletion of nitrates. In 1941 we had enough individuals in a group to give the averages definite significance. In 1945 two fields in the high-yield group were such that high yield was obtained with nitrate content of petioles at a low level. In 1944 one field in the medium-yield group gave petioles exceedingly low in phosphate and highest of all in September tests in nitrate, and thus upset the group average completely. In addition in 1944 an unknown source of interference with the nitrate test caused all low tests to be read falsely high.

In the following table the results of the 3 years are compared on the basis of yield produced per unit of N and P. For this purpose the July and August results are used. The average yield in each group is divided by the average petiole test of that group. The highest factor obtained on any group in 1941 is taken as 100 and all others are calculated proportionally.

Table 5.—N and P performance factors in 1941, 1944, and 1945.

		1941			
Avg. yield of group	21.6	18.3	15.4	12.5	8.9
Fields in group	8	13	16	7	11
Performance:					
Nitrate	100	97	55	84	53
Phosphate	89	100	100	79	63
		1944			
Avg. yield of group		19.4	12.4	9.2	
Fields in group		2	4	3	
Performance:					
Nitrate		129	108	169	
Phosphate		116	70	48	
		1945			
Avg. yield of group		17.1	11.2	7.3	
Fields in group		3	4	3	
Performance:					
Nitrate		102	54	60	
Phosphate		109	63	71	

This table brings out a number of valuable points. If fertility level were the controlling factor in the low-yield fields, the highest performance factors for phosphate or nitrate or both should be found in those groups, since they never have an excess of at least one of the elements. Therefore our interest at present turns to the medium- to high-yield groups. In 1941, a year of high nitrate levels and high average yield, phosphate appeared to control the yield except in the highest yield group where a slight excess probably existed and nitrate controlled.

In 1944, a year of early nitrate depletion, nitrate performance jumped up, as would be expected. Low phosphate performance would be expected. In two of the three groups it was demonstrated, and on one of the two high-yield fields it occurred also.

In 1945, a year of low yields and high nitrates, nitrate performance was low. The explanation of the 102 factor on the high-yield group is that the nitrate tests on two of the high-yield fields dropped to low values early in the season, yet the field produced high yields. In a high nitrate season, high phosphate performance might be expected. If one could explain why during 1945 the activities of the beet went toward developing tops rather than roots, he could probably explain why phosphate performance was low in 1945.

During the 1945 season a number of potash tests were run in an attempt to learn whether inter-relations of N, P, and K content of petioles might show something about fertility which tests for individual components do not indicate. The tests showed increasing potash content of petioles as the season progressed. On August 6 potash content of petioles ranged from 5,000 to 8,000 parts per million of K_2O. Tests on high-yield fields averaged lower than tests on low-yield fields, but no inter-relation of N, P, and K could be worked out which was definitely associated with yields.

It has been necessary to condense the results we have obtained beyond a point where anyone examining those results can find just what has gone into them. The best that can be done is to point out what an examination of all results indicates.

If petiole samples are taken from various plots on the same field, differences in fertility will be reflected by differences in results of tests. But if a single petiole sample is taken from a field, interpretation of the results of the tests is questionable, unless the results are high.

While it appears that on the average a phosphate test of 100 p.p.m. or more is required to produce a sufficiency, it does not follow that applications of phosphate to a crop showing less than 100 p.p.m. will produce a response. Too many exceptions to the rule exist.

The average value for incipient nitrate deficiency appears to be about 400 p.p.m. during the third week of July. It appears that earlier than this date fields which will develop nitrate deficiency do not show it. And if tests are made later, results are known too late to permit of correction of the deficiency without delaying maturity unduly. Again, many exceptions to the rule are to be found.

As a measure of general fertility, where a large number of fields may be sampled and the results averaged, the sugar beet petiole test is very useful.

Many reports of successful application of petiole tests are to be found in the literature. However, the majority of references appear to be perennial crops, such as orchards. Thomas, in Social Science, Vol. 59, p. 353, reviews the subject of tissue analysis and finds analysis of leaf tissue for total components superior to analysis of conducting tissue for unassimilated components if the results are to be correlated with yields. The results we have obtained on analysis for total components have not been encouraging. In 1941 complete analysis was made of total tops from 20 beet fields, 10 fields of high-yield history and 10 fields of low-yield history. Samples were taken twice during the season, first at about July 1 and the second at harvest time. The results show no clear-cut distinctions between tops from fertile and non-fertile fields. The maximum and minimum values are given in table 6.

Table 6.—Maximum and minimum nutrients in beet tops, percent total N, P, and K on dry matter.

	High-yield fields		Low-yield fields	
	Maximum	Minimum	Maximum	Minimum
	Early season samples			
% N	4.9	3.1	4.6	3.0
% P	0.44	0.23	0.40	0.21
% K	4.2	3.0	4.1	3.2
	At harvest time			
% N	3.3	1.8	3.0	1.4
% P	0.25	0.13	0.27	0.11
% K	4.2	1.7	4.9	2.2

Inspection of results on individual samples rarely reveals evidence of inter-relations of N, P, and K levels which may bear a relation to fertility or yields, and even the group averages show rather small differences.

Possibly we ask too much of plant tissue tests, but the demands upon us are severe. Will the field respond to application of fertilizer? We cannot today answer that question on the basis of results from a single sample, regardless of how accurately the sample represents the field, because unknown environmental factors, other than level of available soil nutrients, often control the level of nutrients in the tissue.

Effect of Delayed Lifting After Topping on Certain Chemical Constituents of Sugar Beets

CHARLES PRICE and J. M. FIFE[1]

A large amount of development work to aid in growing and harvesting sugar beets has been done. This work was further stimulated by the war emergency and the need for reducing man hours required to grow the crop. Harvesting machines have received much study. One type of machine used is equipped with knives that top beets in place in the soil. After the topping operation, the leaves and crowns are raked to one side with a side delivery rake and then the roots are lifted by means of a plow. This breaks the connection of root with the soil but leaves it in place. Lifting and operations of removal from the ground and loading are sometimes delayed for several days after the topping operation is completed.

The original purpose of the investigation reported here was to determine the effect of delays in lifting after topping upon certain constituents of sugar beets. It seemed advisable, however, to determine also the effect of delays in removal from the ground upon sugar beets that were both topped and immediately lifted. The effects of the two practices could not be compared on the same days because of the volume of work involved. Samples from the plots topped but not lifted were taken at 2-day intervals; from plots topped and immediately lifted the samplings were at 3-day intervals.

The air temperature prevailing at the time this work was done varied from a daily mean maximum of 106° to a mean minimum of 62° F., while the temperature at the surface of the soil was even higher during the day. These temperatures are extreme, as compared to temperatures of areas in which beets are harvested in the fall, and therefore the changes in constituents of the beets would be greater.

The practice, called delayed topping, of severing the beet roots from the soil several days in advance of topping and hauling them to the factory for processing, has been examined. It was found (*1*)[2] that this procedure results in a loss in sugar yield. This loss is due not only to a direct loss in the field but also to the increase in harmful nitrogen which interferes with recovery of sugar in processing.

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[2]Italic numbers in parentheses refer to literature cited.

Materials and Methods

A field of sugar beets of the variety U. S. 15 growing under favorable conditions near Brawley, Calif., was selected for these studies. The beets were planted on beds with two rows 14 inches apart on each bed. The space between rows of two adjacent beds was 28 inches. The fertility level of the soil in this field was equivalent to that of the better soils of Imperial Valley. The portion of the field chosen had an exceptionally good stand of uniform beets spaced approximately 12 inches apart in the row. The plan of experimentation involved use of a strip of 26 rows approximately 500 feet long. On July 4 all the sugar beets in the experimental area were topped and the crowns and leaves were raked from the top of the bed into the furrow. Eight of the rows were lifted with a beet lifter and the other 18 rows were left unlifted. The lifting operation severed the roots from the soil and lifted them slightly above their growing position. Immediately after lifting, 16 samples of 15 beets each were taken at random for analysis from the experimental area. These were divided into two groups of eight 15-beet samples each. There was no significant difference in sucrose percentage between these two groups. It was, therefore, concluded that eight 15-beet samples constituted an adequate sample. Subsequent sampling was at random for the experimental area concerned, eight 15-beet samples being taken at each sampling period. Samples were taken immediately and at intervals of 2, 4, 6, 8, and 10 days after topping for the test in which the beets were topped but not lifted, and at intervals of 3, 6, and 9 days in the test in which the beets were topped and lifted.

Chemical Analysis

In these studies harmful nitrogen is considered as the nitrogen not precipitated by copper hydroxide minus the total ammonia nitrogen (ammonia plus amid). The methods used for determining harmful nitrogen were essentially those developed by European investigators. These methods are as follows: Three hundred fifty milliliters of distilled water were added to 100 grams of beet pulp and placed in a water bath at 85° C. Fifty milliliters of copper sulphate solution (60 grams of copper sulphate in 1,000 ml. of water) and 50 milliliters of sodium hydroxide solution (12.5 grams of sodium hydroxide in 1,000 ml. of water) were added and thoroughly mixed. The samples were then allowed to digest 15 minutes, with frequent shaking. The samples were cooled to room temperature, the air expelled, made up to volume of 500 ml. and filtered through dry paper pulp. An aliquot of 50 ml. was removed for the determination of the nitrogen not precipitated by the copper hydroxide. Total nitrogen was determined by a standard method which does not include the nitrates. An aliquot of 125 ml. was removed for the determination of ammonia plus amid

nitrogen. The samples were made 1 normal with sulfuric acid and were hydrolized for 2 hours, cooled, then neutralized with sodium hydoroxide. The samples were made alkaline with 40 ml. of an alkaline borate mixture (0.5 normal sodium hydroxide in 5 percent borax) and the ammonia distilled off at atmospheric pressure.

To eliminate so far as possible errors due to differences in percentage dry matter between fresh and flaccid beets, all samples harvested after the first day having a higher percentage of dry matter than fresh beets were corrected to approximately the percentage dry matter of the fresh beets.

Determinations of sucrose percentages followed the procedure used by the Division of Sugar Plant Investigations, U. S. Department of Agriculture. Each 15-beet sample was washed and drained. Each root of the sample was split longitudinally and the pieces were passed under a circular rasp. A fine pulp was rasped from each half beet section and thrown from the circular rasp in a series of layers on a metal band. The entire mass of pulp was taken from the band and thoroughly mixed by an electrically operated mixer. Twenty-six grams of pulp were taken for determination of sucrose percentage. Extraction of sucrose was by the cold water digestion method of Krueger, as modified by Sachs and Le Docte. Two hundred grams of pulp from each of the eight 15-beet samples were placed in a freezing chamber and kept frozen until analyzed for nitrogen constituents.

For reducing sugars, 10 grams of pulp were placed in a 100 ml. Kohlrausch flask and sufficient neutral lead acetate added to clear the extract before the volume was made up to mark. The filtered extract was deleaded with sodium oxalate and again filtered. Reducing sugars were determined on an aliquot, usually 50 ml., of the lead-free filtrate by the Munson-Walker method[2].

Raffinose was determined by an official method [3] for beet products, using hydrochloric acid to invert the sugars before the second polariscope reading.

Experimental Results

Changes in dry matter, harmful nitrogen, sucrose, reducing sugars, and raffinose of beets topped and lifted and topped but not lifted are presented in table 1. A summary of the results is presented in figure 1. A significant increase occurred in percentage of dry matter from the first to the ninth day of the exposure period in the

[2]Association of Official Agricultural Chemists 1934 Official and Tentative Method of Analysis, Washington, D. C.

Table 1.—Results of changes in chemical constituents of sugar beets when topped and left in place with and without lifting.‡

Time after topping	Harmful nitrogen		Sucrose		Dry matter		Reducing sugars	
	Lifted	Not lifted	Lifted	Not lifted	Lifted	Not lifted	Lifted	Not lifted
Days	Grams†	Grams†	Percentage*	Percentage*	Percentage*	Percentage*	Percentage*	Percentage*
0	2.438	2.438	16.0	16.0	23.46	23.46	0.08	0.08
2		2.597		16.0		22.38		0.16
3	3.586		16.6		25.22		0.15	
4		2.569		15.3		22.34		0.71
6	3.128	2.377	15.01	15.7	29.81	22.97	0.47	0.69
8		2.105		15.9		22.87		0.57
9	3.824		13.60		34.33		2.81	
10		2.994		15.2		22.05		0.93

‡Results are averages of eight 15-beet samples.
*Corrected to 22.68 percent dry matter.
†Grams nitrogen per 1,000 grams dry tissue.

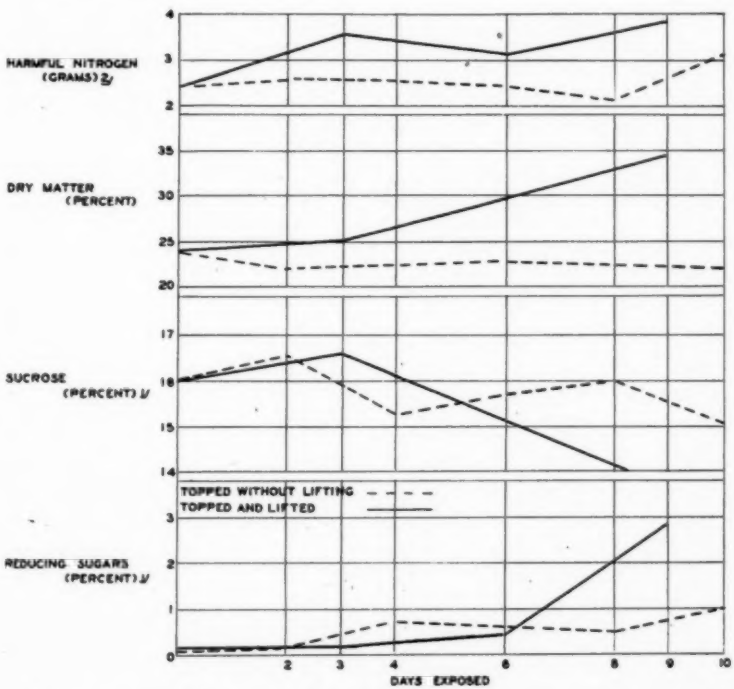

Figure 1.—Changes in chemical constituents of sugar beets when topped and left in place with and without lifting.

beets topped and lifted. In the beets topped but not lifted there was a gradual and significant decrease in percentage of dry matter. This decrease suggests that the beets absorbed moisture from the soil after the tops had been removed. In harmful nitrogen, beets topped and lifted showed a significant increase from the first to the ninth day of exposure. In beets topped but not lifted the harmful nitrogen showed a gradual decrease until the eighth day, and then there was a sharp rise on the tenth day that was statistically significant. Sucrose percentage in the topped and lifted beets showed a gradual and significant decrease from the third to the ninth day. In beets topped but not immediately lifted, the sucrose fluctuated somewhat but significant decrease occurred at the tenth day. In reducing sugars, beets topped and lifted showed a significant increase from the third to the ninth day of exposure. As the period in the soil increased, there was a gradual increase in reducing sugars in beets topped and not immediately lifted, with a sharp increase occurring at the tenth day of exposure.

Summary and Conclusions

A field test was conducted in the Imperial Valley of California in which comparisons were made of changes which took place in sugar beets topped and left undisturbed with those in which the sugar beets were topped and lifted. This test shows that sugar beets topped in place and left unlifted from 1 to 3 days did not change significantly in dry matter, harmful nitrogen, sucrose, or reducing sugars, while beets topped and lifted changed significantly in harmful nitrogen within a 3-day period after the lifting operation. This test also shows that changes occur more rapidly and to a greater extent after the root connections with the soil are broken. It would therefore seem that, after lifting, prompt removal from the soil, loading, and hauling to the receiving station are advisable.

Literature Cited

1. Price, Charles et. al. Sucrose Loss and Changes of Nitrogen Constituents in Sugar Beets under Conditions of Delayed Topping. Jour. Amer. Soc. Agron. 33: 901-907. 1941.

Emergence and Rate of Emergence of Sugar Beet Seed as Influenced by Seed Preparation, Soil Moisture and Temperature

L. D. LEACH, ROY BAINER, and L. D. DONEEN[1]

Processing of sugar beet seed to aid precision planting and to reduce the labor involved in thinning operations constitutes an important phase in the mechanization of sugar beet culture.

Among the methods of seed processing now in use or under experimentation are segmentation, decortication and pelleting. Segmented seed, prepared by methods developed by Bainer (*1*) (*2*)[2], is widely used in commercial plantings. Its chief advantage is in the reduced number of seedlings per viable seed unit and the consequent production of a high percentage of single seedlings. Decorticated seed prepared by the mechanical removal of the cork from beet seed balls was also developed by Bainer (*3*). Seed units prepared in this manner are characterized by uniform size, smooth surface, high density, and high germination. They lend themselves exceptionally well to precision planting but they do not have the degree of singleness shown by segmented seed. Only limited experimental plantings with decorticated seed have been made so far. Pelleting of segmented seed has been described by Reeve (*7*). The final product, because of its uniformity and high density, lends itself to precision planting and the degree of singleness can be controlled by the seed selected for pelleting. Fungicides and fertilizers are also incorporated in some types of pellets.

The present studies were undertaken to determine whether the processing of seeds affects their ability to germinate and emerge at different levels of soil moisture and at high and low temperatures. In addition to the number of seedlings produced, we have considered the rate of emergence, since under fluctuating field conditions small differences in the time required for emergence may determine the success or failure of a planting.

Methods

The segmented and decorticated seeds were prepared by Bainer from the same lot of whole seed (variety U. S. 33, lot 343), samples of which were used for the control. The pelleted seeds were prepared and furnished by the Farmers and Manufacturers Beet Sugar Asso-

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[2]Italic numbers in parentheses refer to literature cited.

ciation, and unpelleted seed from the same lot was used for the control. Samples for each planting were selected mechanically by passing the entire seed lot repeatedly through a Boerner sampler.

All plantings were made in Yolo fine sandy loam soil and at moisture percentages in or close to the range of "readily available moisture", as described by MacGillivray and Doneen (*6*). This range extends from the field capacity, which is the moisture held in a soil when movement has practically ceased after a rain or irrigation, to the permanent wilting percentage (P.W.P.) or the soil-moisture content at which plants wilt and do not recover unless water is added to the soil. When the field capacity is determined in the laboratory, it is known as the moisture equivalent (M.E.). The moisture equivalent for this soil is 15.8 percent and the permanent wilting percentage is 8.8 percent based on the dry weight of soil.

All soil was pasteurized before planting by passing it twice through a soil pasteurizer of the type described by Tavernetti (*8*). The soil was then screened through a 2-mm. screen and the moisture was adjusted by Doneen, using the method described by Doneen and MacGillivray (*4*).

All seeds were planted in friction top cans, each containing 300 grams of soil below and 100 grams of soil above the seeds. Ten whole or decorticated seeds and 15 segmented or pelleted seeds were planted in each can, the difference in numbers compensating for the differences in the number of seedlings per viable seed unit for the seed types.

Each seed type was planted in 10 cans of soil at each soil moisture (8.2, 9.0, 10.2, 13.0, and 16.3 percent) and duplicate plantings were made at temperatures of 50° F. (10° C.) and 70° F. (21° C.). The mean variation in each chamber was less than ± 1° F. during the trials. To measure the rate of emergence, seedlings in each can were counted daily during the emergence period. Each daily increase in emergence was multiplied by the number of days since planting and the sum of the products divided by the total emergence to give the mean emergence period in days as proposed by Leach and Smith (*5*).

Laboratory tests showed the following germination percentages and seedlings per 100 seed units: Whole seed—83 percent and 151 seedlings; decorticated seed—83 percent and 131 seedlings; segmented seed—78 percent and 95 seedlings. Greenhouse tests in pasteurized soil yielded comparable germinations for each seed type.

Experimental Results with Whole, Decorticated, and Segmented Seed

Tests in controlled soil moistures at 70° F. (table 1) showed that all three seed preparations germinated at 9.0 percent and above but

Table 1.—Effect of seed preparation and soil moisture on emergence at 70° F.

	Soil moisture—percent				
	8.2	9.0	10.2	13.0	16.3
Seed preparation	Seedlings per 100 seed units				
Whole	0	113.0	144.0	153.0	162.0
Decorticated	0	112.0	139.0	151.0	137.0
Segmented	0	73.0	91.0	95.0	91.0
	Percent of potential emergence				
Whole	0	75.2	95.5	101.5	107.5
Decorticated	0	85.4	105.8	115.0	104.4
Segmented	0	77.2	95.8	99.7	95.8
	Mean emergence—days				
Whole	—	9.40	6.58	5.50	5.19
Decorticated	—	8.05	5.60	4.77	4.80
Segmented	—	8.32	5.62	4.96	4.66

Permanent wilting percentage—8.8; moisture equivalent—15.8 percent.

not at 8.2 percent, just below the permanent wilting percentage. Reference to the second portion of table 1 shows that a higher percentage of the potential emergence was obtained from decorticated than from whole or segmented seed at lower moisture but not at 16.3 percent, which is above the moisture equivalent.

According to table 1, both decorticated and segmented seed germinated more rapidly than whole seed at all soil mostures, as indicated by the mean emergence period. The emergence curves, in figure 1A, show striking differences at 9 percent soil moisture, whereas at 13 percent (figure 1B) smaller differences occurred.

At 50° F. (table 2) a longer emergence period was required and differences in emergence rates are more obvious than at 70° F. Decorticated seed again produced a higher percentage of potential emergence at 9 and 10 percent than whole or segmented seed, but this relation was apparently reversed at 16.3 percent.

Table 2.—Effect of seed preparation and soil moisture on emergence at 50° F.

	Soil moisture—percent				
	8.2	9.0	10.2	13.0	16.3
Seed preparation	Seedlings per 100 seed units				
Whole	0	137.0	144.0	140.0	152.0
Decorticated	3	127.0	142.0	124.0	118.0
Segmented	0	81.0	87.0	93.0	93.0
	Percent of potential emergence				
Whole	0	91.0	95.6	93.0	100.8
Decorticated	2.3	96.8	108.2	93.0	89.2
Segmented	0	85.2	91.6	97.9	97.9
	Mean emergence period—days				
Whole	....	24.37	17.39	14.98	14.76
Decorticated	....	20.66	16.45	14.47	14.66
Segmented	....	23.72	17.02	14.79	14.55

Permanent wilting percentage—8.8; moisture equivalent—15.8 percent.

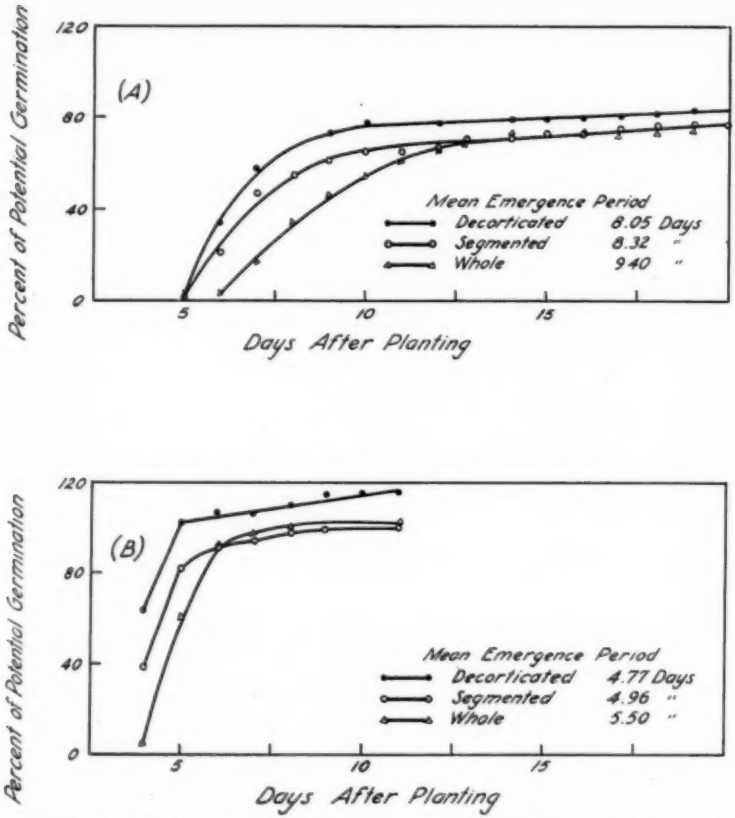

Figure 1.—Effect of preparation of sugar beet seed on emergence of seedlings at 70° F. A: At 9 percent soil moisture decorticated seed showed a mean emergence period 1.35 days less than whole seed while segmented seed was intermediate in emergence rate; B: At 13 percent soil moisture each seed type showed only about half as long an emergence period as at 9 percent but the order of emergence was the same.

The emergence period for decorticated seed at 9 percent soil moisture was considerably shorter than that for whole or segmented seed, but as the moisture increased, the differences in rate of emergence decreased. Figures 2A and B show the effect of seed processing on the time required for emergence in 9 and 13 percent soil moisture at 50° F. By the twentieth day after planting, when emergence of decorticated seed in 9 percent soil moisture was 56 percent completed, whole seed showed only 14 percent and segmented seed 20 percent of their potential emergence. Such a difference would be extremely important if conditions during germination became sufficiently unfavorable to prevent late emergence.

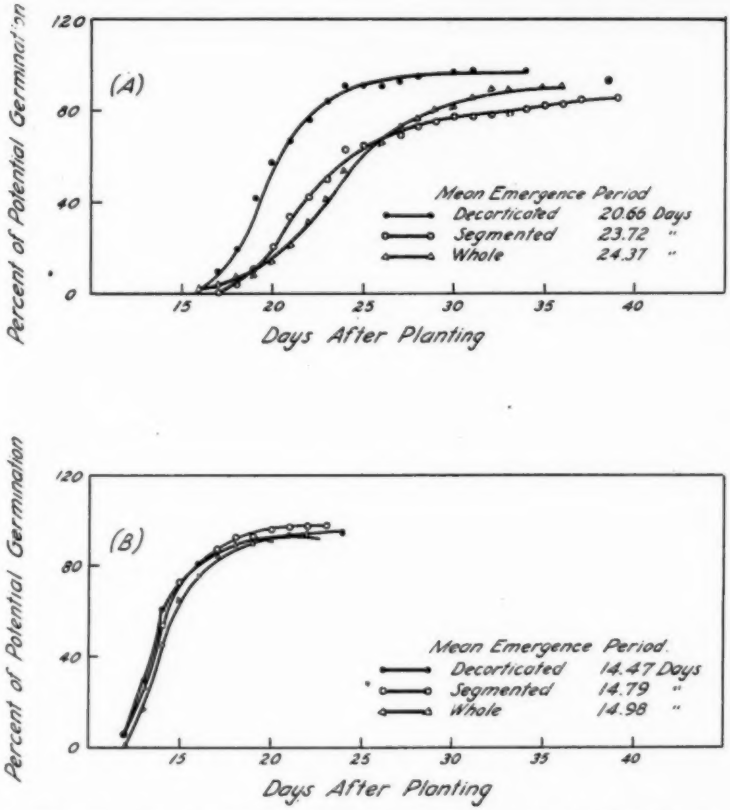

Figure 2.—Effect of preparation of sugar beet seed on emergence of seedlings at 50° F. A: At 9 percent soil moisture, decorticated seed showed a mean emergence period 3.7 days shorter than whole seed B. At 13 percent soil moisture, however, there was less than a day difference in the mean emergence periods of whole, segmented, or decorticated seeds.

The effect of soil moisture upon the mean emergence period for whole, segmented, and decorticated seeds at both high and low temperatures is shown in figure 3. As indicated previously, the greatest differences occur at low soil moistures and at a low temperature.

Separate tests conducted in greenhouse soil have shown that with seed of comparable quality, whole sugar beet seed germinates more slowly than either segmented or decorticated seed and that emergence from decorticated seed is the most rapid. It is believed that the removal of the outer portions of the beet seed ball during processing increases the rate of moisture absorption and thus hastens germina-

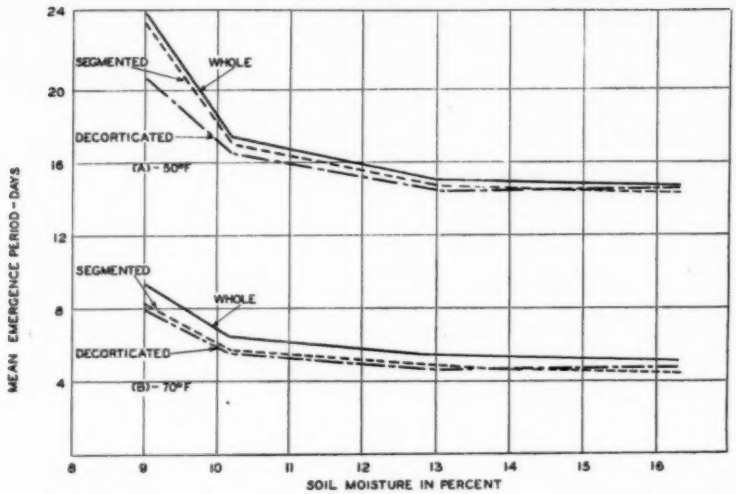

Figure 3.—Effect of soil moisture on the time required for emergence of whole, segmented, and decorticated sugar beet seed at (A) 50° F. and (B) at 70° F. It required three times as long for seedlings to emerge at 50° as at 70° F. Practically no emergence occurred below the permanent wilting percentage—8.8. Emergence rates at soil moistures between 10 percent and above the moisture equivalent, 15.8 percent, differed only slightly, but at 9 percent emergence was delayed by several days. Decorticated seed germinated considerably faster than segmented or whole seed at 9 percent soil moisture, but at higher soil moistures the differences between seed types were less pronounced.

tion. This opinion is supported by the fact, illustrated in tables 1 and 2, that the differences in time required for emergence are greater at low than at high soil moistures. Lowering the temperature from 70° to 50° F. more than doubled the time required for emergence and the differences in emergence rates were similarly affected.

Experimental Results with Segmented and Pelleted Segmented Seed

To determine how pelleting of segmented sugar beet seed affected the emergence and rate of emergence at different soil moistures and at high and low temperatures, a similar series of trials was conducted using seed prepared and furnished by the Farmers and Manufacturers Beet Sugar Association.

Preliminary to the controlled experiments two greenhouse plantings were made in pasteurized soil, one on April 6, 1945, a few days after the seeds were received, and the other on October 26, 1945, after the seeds and pellets had been stored for 6 months in a dry laboratory.

The results in table 3 show that the emergence from both white and blue pellets was somewhat lower than from the unpelleted seed and that the pellets required a longer emergence period.

Table 3.—Effect of pelleting segmented sugar beet seed upon emergence and rate of emergence, greenhouse plantings in sterile soil.

Seed preparation	Moisture addition during germination	Trial of April 6, 1945[1] Emergence per 100 seed units	Trial of April 6, 1945[1] Mean emergence period—days	Trial of Oct. 26, 1945[2] Emergence per 100 seed units	Trial of Oct. 26, 1945[2] Mean emergence period—days
Segmented—unpelleted	watered	88	8.95	75	6.47
Segmented—unpelleted	not watered	....[3]	....	62	7.51
Segmented—white pellets	watered	51	10.41	50	8.22
Segmented—white pellets	not watered	....	....	38	10.96
Segmented—blue pellets	watered	59	11.55	23	10.94
Segmented—blue pellets	not watered	....	....	30	16.16
Significant difference 99:1 odds		14.7	0.86	13.4	1.36

[1]Temperature range—43° to 89° F.; mean—61° F.
[2]Temperature range—52° to 83° F.; mean—64° F.
[3]Not tested.

After 6 months storage the white pellets showed the same relation to the unpelleted seed as in the original trial, but the blue pellets were noticeably lower in germination and slower to emerge. The deterioration of the blue pellets was probably due to the incorporation of organic mercury fungicides in the pellets and was predicted by the manufacturer.

Withholding water until the seedlings started to emerge delayed the germination of all lots, but the effect was more pronounced upon the pelleted seeds.

In the trials conducted in constant soil moistures at both 70° F. and 50° F. (tables 4 and 5) unpelleted seeds again produced more seedlings per 100 seed units than either white or blue pellets. As soil moistures were lowered, differences in emergence increased. The poor performance of the blue pellets, however, is probably due to chemical injury during storage, as indicated above.

Table 4.—Effect of pelleting on emergence and rate of emergence of segmented seed at 70° F.

Seed preparation	Soil moisture—percent 8.1	9.2	10.3	13.1	16.3
	Seedlings per 100 seed units				
Segmented—unpelleted	0	61	81	76	77
Segmented—white pellets	0	26	59	68	61
Segmented—blue pellets	0	5	23	45	27
	Mean emergence period—days				
Segmented—unpelleted	....	7.89	6.00	5.14	5.09
Segmented—white pellets	....	10.90	8.24	6.51	7.09
Segmented—blue pellets	....	13.25	14.86	12.42	14.70

Permanent wilting percentage—8.8; moisture equivalent—15.8 percent.

Table 5.—Effect of pelleting on emergence and rate of emergence of segmented seed at 50° F.

	Soil moisture—percent				
	8.1	9.2	10.3	13.1	16.3
Seed preparation	Seedlings per 100 seed units				
Segmented—unpelleted	0	74	80	78	77
Segmented—white pellets	0	47	55	60	63
Segmented—blue pellets	0	14	38	42	28
	Mean emergence period—days				
Segmented—unpelleted	....	21.28	19.21	15.68	15.51
Segmented—white pellets	....	28.83	24.83	19.59	19.40
Segmented—blue pellets	....	35.68	29.38	25.08	29.07

Permanent wilting percentage—8.8; moisture equivalent—15.8 percent.

The time required for emergence of the white pellets was greater than for unpelleted seeds, and the differences increased at the lower soil moistures. Emergence curves at 13 percent soil moisture are shown in figure 4.

These results can be interpreted only as applying to the particular seed lots furnished for these tests and may not be typical of the performance of other lots or preparations. They do indicate, however, that with this seed lot the coating applied to the seed increased the difficulty of germination. With the white pellets, emergence at both 50° and 70° F. was improved by an ample supply of soil moisture.

Summary

To determine whether the processing of sugar beet seeds affected their ability to germinate, samples of whole, decorticated, segmented, and pelleted seeds were tested in a series of soil moistures and at high and low temperatures.

All plantings were made in cans containing pasteurized soil adjusted to certain moisture levels ranging from near the permanent wilting percentage to near the field capacity. Duplicate plantings were made at 50° F. (10° C.) and at 70° F. (21° C.).

It was found that decorticated sugar beet seed germinated faster and showed a higher percentage of potential emergence than whole seed at low soil moistures. Segmented seed in most cases was intermediate between whole and decorticated seed. At high soil moistures there were only slight differences in rates of emergence between whole, decorticated, and segmented beet seed.

Pelleted beet seeds tested in the same manner showed a lower emergence and a longer emergence period than unpelleted seed from the same source. In low soil moistures the delay in emergence from pelleted seeds was more pronounced.

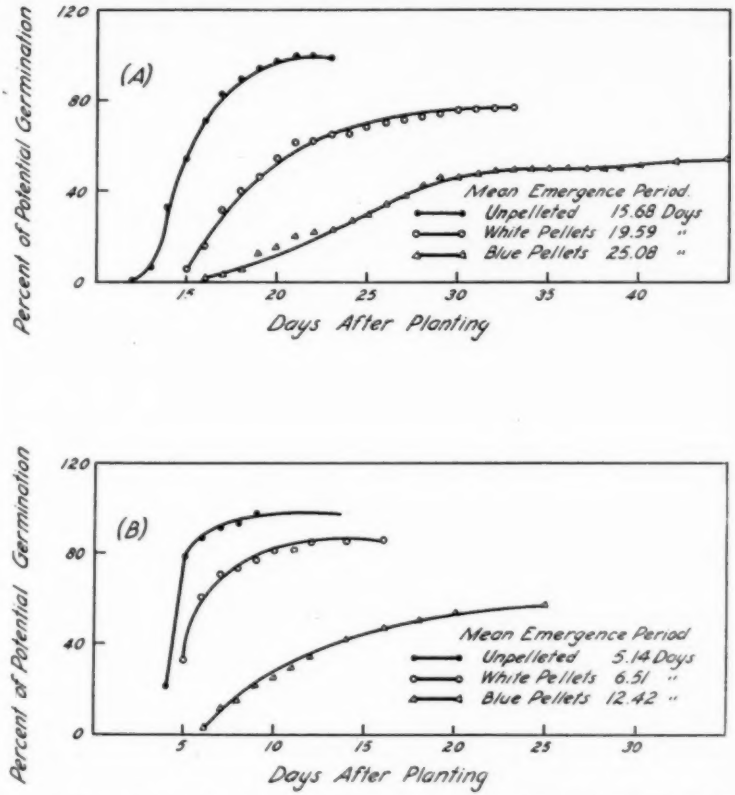

Figure 4.—Comparison of the emergence rates of segmented and pelleted sugar beet seed at 13.1 percent soil moisture and at (A) 50° F. and (B) 70° F. The white pelleted seed which contained cuprous oxide and chloronil germinated somewhat more slowly than the unpelleted seed, and the delayed emergence was more pronounced at the lower temperature. The extreme delay of emergence shown by the blue pellets, which contained an organic mercury fungicide, was due in part to chemical injury during 6 months storage and would not be typical for a fresh preparation.

At 50° F. the emergence periods for all seed lots were more than twice as long as at 70° F., and the difference between emergence rates for the various seed preparations were correspondingly increased.

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A Method of Reducing Storage Loss In Siloed Beet Pulp

J. E. Coke and R. D. Jones[1]

The loss of solids and nutrients contained in pulp of sugar beets stored in open silos in California is of such magnitude that an investigation was undertaken to determine methods of reducing this loss.

Skirmish tests were conducted at Manteca and Woodland,[2] Calif., in which the loss of dry matter contained in untreated and unpressed beet pulp stored in small trench silos, wooden barrels and steel pipes, varied from 53 percent to 82 percent for a storage period of slightly over 200 days. The high losses obtained from these skirmish tests are in line with the experience of commercial operators of open beet-pulp silos.

Beet sugar factories, which do not dry beet pulp, pump the wet pulp to large open storage silos where the pulp is passed over screens for removal of most of the free water. The pulp as it enters the silo contains in the neighborhood of 98 percent moisture. Since cattle feeding operations in California are generally carried on throughout the year, some pulp may be in storage for as long as 300 to 360 days.

Bacteria responsible for the formation of butyric acid cause one form of fermentation which is responsible not only for the strong and decidedly unpleasant odor of beet pulp silage but to a considerable degree also for the very heavy loss of solids and nutrients experienced when beet pulp is ensiled.

During the past 2 decades a considerable amount of research and investigational work has been carried on in Europe and in this country on the addition of preservatives to green fodders before placing in silos for fermentation and storage, but almost no work has been conducted using beet pulp.

Three methods of fodder preservation have been generally accepted as standard:

1. The A. I. V. process, developed and patented by A. I. Virtanen of Finland. This process uses hydrochloric and sulphuric acids to bring the material to be ensiled to a pH of about 3.5.
2. The use of molasses, either beet or cane, as the preserving agent.
3. The use of phosphoric acid, instead of hydrochloric and sulphuric acids used in the A. I. V. system.

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[1]Spreckels Sugar Company, San Francisco, Calif.

[2]Unpublished data, Spreckels Sugar Company, San Francisco, Calif.

Plan of Beet Pulp Preservation Experiment

Preliminary experiments had indicated that unless some of the moisture normally in pulp as it enters the silo was removed prior to the addition of preservatives, the treatments were not effective in reducing pulp losses.

Therefore, an experiment was designed using pressed pulp (moisture content varying from 85.3 percent to 91.3 percent) with the following five treatments:

1. Pressed pulp — No treatment.
2. Pressed pulp mixed with 2½ percent (by weight) cane molasses.
3. Pressed pulp mixed with 5 percent (by weight) cane molasses.
4. Pressed pulp mixed with 7½ percent (by weight) cane molasses.
5. Pressed pulp mixed with 2N-hydrochloric and sulphuric acids in sufficient quantity to give a pH of 3.5.

The molasses and the acid were mixed with the pulp in a concrete mixer after which it was placed immediately in the storage bins.

There were 20 wooden, paper-lined bins, each 8 feet by 8 feet in width by 6 feet in depth. Four bins were used for each treatment; each bin held approximately 10 tons of pressed pulp. The ouside walls of the bins were banked with earth to exclude air and minimize the effect of changes in atmospheric temperature in the storage tests.

The pulp and other ingredients were weighed and analyzed as they were placed in and removed from their respective bins, and samples of pulp were removed from each bin and analyzed at the end of each 30-day storage period.

Experimental Results

Cane molasses mixed with pressed pulp in quantities varying from 2½ percent to 7½ percent (by weight) and acid (2N-hydrochloric and sulphuric) mixed with pressed pulp in quantities sufficient to give a pH of 3.5 reduced substantially the amount of dry matter and total nutrients lost during a storage period in excess of 200 days as compared with losses from the storage of plain pressed beet pulp.

Pressed pulp (untreated) held in storage for slightly over 200 days lost 51.88 percent of the dry matter as compared with a loss of 32.46 percent when treated with 2½ percent molasses; 18.60 percent when treated with 5 percent molasses; and 25.86 percent when treated with 7½ percent molasses. The loss of solids, when treated with acid, was 20.41 percent.

The loss of nutrients was slightly higher than the loss of solids. Total nutrients lost from the untreated pressed beet pulp were 58.54 percent compared with a loss of 38.78 percent when treated with molasses at the rate of 2½ percent by weight, a loss of 23.15 percent when treated with molasses at the rate of 5 percent, and 28.37 percent for a molasses treatment of 7½ percent; the loss from the acid treatment was 23.38 percent.

These tests indicate that mixing pressed beet pulp with cane molasses at the rate of 5 percent molasses, by weight, or mixing pressed pulp with a mixture of hydrochlorie and sulphurie acid in quantities to give a pH of 3.15 resulted in reducing the loss of dry matter in nutrients by more than one-half for a storage period of over 200 days.

Recovery of solids and nutrients from molasses-treated, acid-treated, and plain pressed beet pulp held in storage bins.

Treatment:	No treatment	2½ percent cane molasses	5 percent cane molasses	7½ percent cane molasses	.2N-hydrochlorie and sulphurie acid-pH of pulp 3.5
Days in storage	228	212	216	210	206
Total dry matter:					
Introduced—pounds	204.90	254.23	300.01	366.16	267.37
Recovered—pounds	98.66	172.29	243.04	274.00	212.19
Loss—percent	51.88%	32.46%	18.60%	25.86%	20.41%
Total Nutrients:					
Introduced—pounds	151.14	193.48	232.22	282.58	190.01
Recovered—pounds	62.71	118.85	177.48	204.79	145.24
Loss—percent	58.54%	38.78%	23.15%	28.37%	23.38%
Proteins:					
Introduced—pounds	18.12	20.23	23.61	26.81	21.33
Recovered—pounds	12.26	17.99	22.33	23.44	18.93
Loss—percent	32.29%	11.38%	5.02%	13.32%	10.80%
Carbohdrates:					
Introduced—pounds	133.03	173.25	208.62	255.78	168.69
Recovered—pounds	50.45	100.86	155.16	181.35	126.32
Loss—percent	62.11%	41.97%	25.20%	29.93%	24.96%
Crude Fiber:					
Introduced—pounds	48.11	48.43	51.83	50.79	56.24
Recovered—pounds	31.77	41.64	48.33	48.72	53.75
Loss—percent	33.97%	13.90%	6.12%	18.88%	4.28%
Ash:					
Introduced—pounds	5.66	12.33	15.97	23.80	21.13
Recovered—pounds	4.20	11.81	17.24	20.50	13.20
Loss—percent	25.73%	1.11%	(7.86%)	11.36%	37.18%

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Agronomic Studies Related to Mechanization of Sugar Beet Culture

H. E. Brewbaker, R. R. Wood, and H. L. Bush[1]

In the search for methods of mechanization in the growing of sugar beets, Spring cultural operations are largely interdependent in that each operation has a critical influence upon those to follow. For the purposes of study, however, we usually attempt to break down the Spring tasks into parts, to permit of more careful scrutiny. This report, therefore, will follow as much as possible the above principle of segregation of subjects.

Planter Studies

Planter investigations, in comparison with those undertaken by other investigators, have been on a rather limited scale. Six different drills were tested at Windsor, Colo. Of these six, three were also tested at Billings, Mont. The comparative results are presented for both locations in table 1.

Table 1.—Planter studies, 1945. Windsor, Colo., and Billings, Mont.

Germination stand data						
Drill	Location	Total seedlings	Percentage[1] singles	Percentage of potential germination	Percentage stand	Max. gap, inches
J. D. smooth tube—low can	Windsor	47.4	38.4	78.8	30.6	11.2
J. D. smooth tube—high can	Windsor	34.4	42.5	49.1	23.3	16.7
J. D. experimental drill	Windsor	32.0	47.6	62.5	22.8	16.7
I. H. C. drill No. 40	Windsor	31.7	42.1	70.3	21.4	16.4
Cobbley unit drill	Windsor	31.7	51.4	71.5	23.2	14.8
Ford Experimental Drill	Windsor	24.4	48.0	30.8	17.2	24.7
J. D. smooth tube—high can	Billings	21.4	71.5	63.8	18.1	15.2
I. H. C. drill No. 40	Billings	25.6	74.6	74.6	22.2	14.6
Cobbley unit drill	Billings	27.5	62.2	81.9	22.1	12.5

All counts based on 100 inches of row.

[1]Percent of seedlings as singles, i. e., only 1 seedling per inch.

Plots: 4 rows x field length at Billings and 8 rows x field length at Windsor.

Replications at each location=1.

No harvest data.

The percentage of single plants is considerably higher for Billings in the three comparisons where the same drill was used at both places. This difference is probably accounted for by the lighter rate of seeding at the Billings location which was 3 pounds of seed per acre as compared with 4 to 6 at the Windsor location.

[1]Director of Experiment Station, Agronomist, and Statistician-Agronomist, respectively, Great Western Sugar Company, Longmont, Colo.

Type of Planting

Three methods of seed coverage were used at three locations, combined with seeding rates and dates of planting. The comparisons are (1) flat or standard method and depth of seed placement; (2) furrow planting, in which the seed was placed at a depth of 2 to 2½ inches (the object being to place the seed into moist soil) with immediate removal of approximately the top inch of dry soil, thus permitting seedling emergence in the usual length of time; and (3) ridge-cover, an operation whereby a ridge of soil several inches in depth was thrown over the planted seed and removed 4 to 5 days later after the seed had germinated. The principal object of this last type of planting was to hold soil moisture at a higher level immediately around the seed until germination was accomplished.

The results of these trials are summarized in table 2.

The wide variations and sometimes reversals between dates at the same location are explained by changing soil moisture conditions. One difficulty encountered with the "furrow" type of planting was in closing the seed furrow after the disk-furrow opener; this open furrow permitted drying out of the soil moisture immediately adjacent to the seed with consequent reduction in seedling emergence.

One advantage of the ridge-cover type of planting, other than moisture considerations, is weed control. It was found at Longmont that those plots in which the rows were ridged and later harrowed off were much more free of weeds than either of the other types of planting.

In removing the ridges of the ridge-cover treatments at Longmont, the operation was conducted by placing a 1-inch by 3-inch board in front of the front row of harrow teeth, the implement being driven lengthwise of the rows; by this method at this location, insufficient soil was removed from about the seed. An excess of moisture, as rain, for all cases except June 20 and 26 at Longmont was not conducive to success with either the furrow or ridge-cover methods of planting since the principal objective for either of these methods is to place or hold the seed in moist soil for germination when soil moisture might be insufficient for the usual flat method of planting.

Row Width and Spacing

Increasing the distance between rows would result in a rapid and positive saving in labor. Two widths of row wider than commonly employed, combined with two spacings within the rows, were compared with standard widths at each of three locations. These treatments consisted of (1) alternating narrow and wide rows with 8- and 12-inch spacings within the row, and (2) wide rows with 6- and

Table 2.—Coverage and rate of planting study. Germination stand counts, Billings, Longmont, and Windsor, 1945.

Location	Date planted	Rate of planting Pounds per A.	Total No. Seedlings per 100 in.			No. singles per 100 in.			Maximum gap—inches		
			Flat	Furrow	Ridge-cover	Flat	Furrow	Ridge-cover	Flat	Furrow	Ridge-cover
Billings	April 12	3.24	18.70	7.80	13.50	11.50	5.00	9.60	18.20	47.10	25.30
Billings	May 1	3.24	28.00	17.00	31.80	20.00	11.40	18.50	19.20	23.30	8.70
Billings	June 21	3.24	15.30	22.00	18.00	11.00	15.80	15.20	26.00	18.80	19.00
Billings	July 3	3.24	12.10	8.80	12.10	8.80	6.80	9.60	22.50	28.80	27.50
Longmont	May 4	2.91	46.58	50.00	40.31	20.00	20.94	17.81	11.17	11.31	13.75
Longmont	May 8	2.91	31.06	43.19	12.63	17.56	19.25	9.44	13.94	11.00	27.81
Longmont	June 13	1.88	22.88	19.41	17.25	11.94	11.07	10.06	19.00	23.07	20.81
Longmont	June 13	2.91	34.50	24.25	22.81	19.38	16.33	13.94	14.06	18.75	20.75
Longmont	June 13	4.38	40.81	27.88	24.19	21.25	16.31	13.81	13.75	19.44	23.13
Longmont	June 20	1.88	2.25	3.81	1.50	1.44	2.44	1.13	77.56	69.38	81.69
Longmont	June 20	2.91	2.44	5.75	2.63	1.94	5.00	2.13	77.31	54.31	73.56
Longmont	June 20	4.38	3.44	10.69	5.50	2.88	6.63	4.06	77.38	54.56	66.44
Longmont	June 26	2.91	0.00	2.31	0.00	0.00	1.94	0.00	100.00	72.94	100.00
Windsor	May 3	5.00	49.56	33.88	38.13	17.38	13.88	14.69	11.94	14.81	16.56
Windsor	May 3	5.00	23.69	18.38	18.50	13.63	10.94	9.25	15.38	19.94	24.38
Windsor	May 7	5.00	51.60	34.13	25.38	18.13	14.13	12.88	10.88	16.94	20.50
Windsor	May 18	5.00	20.88	18.75	18.88	12.94	14.44	13.13	22.88	21.50	21.44
Average		3.53	23.72	20.46	17.83	12.28	11.31	10.30	32.42	30.94	34.78

Design of experiment:
Single four-row plot of each treatment, each date or replicate.
Windsor—300 feet in length
Longmont—380 feet in length
Billings—450 feet in length
No harvest data

10-inch spacings within the row. The above treatments were compared with narrow rows with 12-inch spacings as standard. These comparisons are presented in table 3.

Table 3.—Summarized resulted for width of row and spacing presented as averages for three locations, viz., Billings, Longmont, and Windsor, 1945.

Treatment[1]	Tons beets per A.	Percentage sugar	Pounds sugar per A.	No. beets per 100 feet of row
Narrow row, 12-inch spacing	17.95	16.52	5931	106.8
Narrow-wide alternate row, 12-inch spacing	15.79	16.12	5091	105.5
Narrow-wide alternate row, 8-inch spacing	15.35	16.16	4961	120.1
Wide row, 10-inch spacing	14.74	15.90	4687	116.2
Wide row, 6-inch spacing	14.06	15.94	4482	151.1
General mean	15.58	16.13	5026	119.9
CV (percent)	4.02	1.18	4.09	..
LSD 5 percent pt.	1.15	.35	381	..
LSD 1 percent pt.	1.60	.50	532	..

[1]Hand work at Longmont and Windsor with rows 20 inches (narrow) and 40 inches (wide) in width long-handled hoe at Billings with rows 22 inches (narrow) and 44 inches (wide) in width.

Design of experiment:

3 replications at each of three locations.

Plot lengths—Longmont—380 feet
Windsor—300 feet
Billings—450 feet

Rows per plot—Longmont and Windsor—8 rows for 20-inch, and alternate 20-inch-40-inch rows; 6 rows for 40-inch rows.
Billings—6 rows for 22-inch rows.
4 rows for alternate 22-inch-44-inch rows.
3 rows for 44-inch rows.

Harvest—10 samples of 10 feet of row for each plot at Longmont and Windsor; entire plot yields at Billings.

It should be pointed out that in these tests increasing the population in the wider rows by closer spacing within the row did not result in an increase in acre yield; the difference, while not amounting to significance, is pointedly in favor of wider spacing.

At two locations, Longmont and Windsor, Colo., a third treatment was added to those discussed above; namely, row width of 30 inches, with 8- and 12-inch plant spacing, results for which are presented in table 4.

While the space relationship per plant in the 30-inch rows would be the same as for the alternating 20-40-inch, apparently in these two comparisons the 30-inch treatment produced more sugar per acre, but not by a significant amount.

Table 4.—Summarized results for width of row and spacing presented as averages for two locations, viz., Longmont and Windsor, 1945.

Treatment	Tons beets per A.	Percentage sugar	Pounds sugar per A.	No. beets per 100 feet of row
20-inch row, 12-inch spacing	18.83	16.35	6144	103.2
Alternate 20-inch-40-inch row, 12-inch spacing	16.21	15.48	5016	102.8
Alternate 20-inch-40-inch row, 8-inch spacing	15.64	15.75	4924	116.2
30-inch row, 12-inch spacing	17.01	15.46	5265	105.2
30-inch row, 8-inch spacing	16.30	15.56	5089	122.0
General mean	16.80	15.72	5292	109.9
CV (percent)	5.58	1.61	5.70	..
LSD 5 percent pt.	1.61	.31	530	..
LSD 1 percent pt.	3.15	.43	735	..

Design of experiment:
3 replications at each of 2 locations.
Plots—8 rows x 380 feet at Longmont
8 rows x 300 feet at Windsor
Harvest—10 samples of 10 feet of row for each plot.

Method of Mechanical Thinning

In general, two methods of reducing the beet population in the row mechanically have proved usable, viz., (a) cross blocking, or running tools perpendicular to the row direction, and (b) "down the row" machines exemplified by the Dixie Beet Thinner, used in these tests, which has a system of revolving knives. Essentially the accomplishment is the same with either machine, but conditions in any given field can make one type operate more satisfactorily than the other.

Three population levels, as left by the Dixie Beet Thinner, were compared at two locations with standard hand thinning and with long-handled-hoe thinning. The harvest results for two locations are given in table 5.

In another test cross blocking by use of cultivator tools running perpendicular to the direction of the rows was compared with conventional hand thinning and thinning by long-handled hoe only. Results for each of three locations are given in table 6.

It may be pointed out here that in each case thinning by means of a long-handled hoe only resulted in very moderate reductions in acre yield at any of the three locations.

In order to test out on an extensive and practical scale the possibilities of complete mechanization of thinning, an offer was made

Table 5.—Summarized results for Dixie Beet Thinner operation at two locations, viz., Longmont and Billings, 1945.

Longmont				No. beets per 100 feet of row	
Treatment	Tons beets per acre	Percentage sugar	Pounds sugar per acre	Harvested	After thinning
Hand block and thin, 12-inch spacing	15.70	14.50	4553	104.1	107.0
Long handled hoe only, 12-inch spacing	15.10	14.77	4461	131.9	161.5
Dixie Beet Thinner, 150 beets per 100 feet	14.11	14.43	4072	106.0	146.0
Dixie Beet Thinner, 125 beets per 100 feet	13.21	14.18	3746	87.9	131.2
Dixie Beet Thinner, 100 beets per 100 feet	14.21	14.75	4192	97.5	107.0
General mean	14.47	14.53	4205	105.5	130.0
CV (percentage)	5.62	2.29	6.25	....	....
LSD 5-percent pt.	.99	.41	320	....	....
LSD 1-percent pt.	1.36	*	440	....	....
Billings					
Hand block and thin, 12-inch spacing	17.59	16.60	5840	....	94.6
Long handled hoe only, 12-inch spacing	16.79	16.50	5638	....	135.5
Dixie Beet Thinner, 150 beets per 100 feet	15.18	16.50	5009	....	166.5
Dixie Beet Thinner, 125 beets per 100 feet	15.02	16.80	5047	....	149.7
Dixie Beet Thinner, 100 beets per 100 feet	14.82	16.70	4950	....	121.8
General mean	15.88	16.62	5279	....	133.6
CV (percentage)	5.57	2.63	6.28	....	....
LSD 5-percent pt.	1.07	*	398	....	....
LSD 1-percent pt.	1.45	*	543	....	....

* Not significant

Design of experiment: Randomized block

Plots—4 rows x 195 feet at Longmont
4 rows x 700 feet at Billings

6 replicates at each location

Harvest—2 rows of each plot taken at Longmont for yield. Samples for sugar determination taken at random from these 2 rows. All 4 rows taken at Billings for yield. Two samples for sugar determination taken at factory dump from load delivered.

by the Great Western Sugar Company to reimburse for any net losses certain growers who were willing to cooperate in mechanizing one-half of a field up to 10 acres in size as compared with the other half, thinned entirely by hand. The hoeing and weeding operations were the same on either half of the field, except that in most cases a hoe-trimming operation followed the machine blocking, while in other cases the regular hoeing was increased somewhat where the hoe-trimming was not

Table 6.—Summarized results for cross blocking and cross cultivation tests, 1945, Longmont, Billings, and Windsor.

Treatment	Tons beets per acre	Percentage sugar	Pounds sugar per acre	No. beets per 100 feet of row	
				Harvested	After thinning
Longmont					
Hand block and thin	15.88	13.26	4211	84.2	88.7
Cross block and cross cultivate	15.00	12.67	3801	62.4	65.9
Long-handled-hoe thinning	15.18	13.27	4029	94.5	150.0
General mean	15.35	13.07	4011	80.4	101.5
CV (percentage)	3.14	1.66	4.27	....	....
LSD 5-percent pt.	.56	.25	200	....	....
LSD 1-percent pt.	*	.35	280	....	....
Billings					
Hand block and thin	18.50	17.20	6364	81.4	76.5
Cross block	16.20	17.30	5605	98.7	68.5
Long-handled-hoe thinning	16.96	17.50	5936	114.5	91.5
General mean	17.22	17.31	5962	98.2	78.8
CV (percentage)	3.02	.67	3.09	....	....
LSD 5-percent pt.	.56	.13	197	....	....
LSD 1-percent pt.	.77	.17	274	....	....
Windsor					
Hand block and thin	14.71	17.32	5096	84.2	94.8
Cross block	13.41	17.37	4659	113.9	105.3
Long-handled-hoe thinning	14.59	17.39	5074	92.0	90.2
General mean	14.24	17.36	4944	96.7	96.8
CV (percentage)	8.93	2.00	8.60	....	....
LSD 5-percent pt.	*	*	*	....	....
LSD 1-percent pt.	*	*	*	....	....

* Not significant

Design of experiment: Randomized block

Plots—20 feet x 60 rows at Longmont
22 feet x 100 rows at Windsor
20 feet x 160 feet at Billings

Replicates—Longmont=7
Windsor =8
Billings =8

Harvest—Longmont and Windsor—18 feet of row per sample, 6 samples per plot. Billings—36 feet of row per sample, 10 samples per plot.

done. A total of 41 farms were included in this test, the results being summarized to table 7 for the principal districts of the Great Western area.

In figuring the net return all regular beet labor costs were used, this figure representing the cash return to the grower for his part in growing the crop and delivering it to the factory. The actual saving

Table 7.—Summarization of yield, labor cost, and financial returns for cross blocking and hoe trimming ("Mech") as compared with hand thinning ("Hand").

District	No. farms	Yield tons roots per acre		Total labor cost per acre		Net cash return per acre	
		Hand	Mech.	Hand	Mech.	Hand	Mech.
N. Colorado	17	14.29	11.94	$35.91	$24.29	$145.59	$123.79
E. Colorado	10	12.73	10.65	33.06	25.63	120.68	102.80
Nebraska	9	11.78	10.28	31.83	22.84	101.96	93.82
Wyoming	1	9.85	7.70	30.81	19.78	104.92	88.10
Montana	4	12.26	9.95	19.63	13.38	143.86	119.29
	41						

in hand labor amounted to 28 percent as an average of all 41 farm tests, the net cash return for the mechanized operation being 15 percent less than for hand work. This experiment needs to be considered not so much with respect to the rather small loss in return from the mechanized operation as compared with hand work, but as a first experience by 41 different growers, each of whom could, not doubt, improve their work and results for a second experience with a mechanized operation.

Summary

None of the tests here presented give a method of producing the beet crop mechanically and still maintain yields equivalent to those obtained by hand thinning of the plants. The reductions in yield in many comparisons are relatively small, demonstrating that in conditions of reduced labor supply, methods are available for continued production of the sugar beet crop.

It would seem that, without doubt, experience in mechanical thinning operations will result in greater proficiency on the part of growers in handling this kind of work. As such knowledge is gained, we should expect acre yields to rise toward those of conventional hand thinning. It is not inconceivable that ultimately we can surpass, by mechanical operation, the yields now obtained by hand thinning.

Effect of Temperature Upon the Growth Rate of Sugar Beets

L. T. Pierce and R. R. Wood[1]

It is generally recognized that a relationship exists between temperature and the growth rate of plants and that there is a difference in the optimum temperature at which different genera produce maximum growth. Several examples of such difference were pointed out by Hilgard (*3*)[2]. This is substantiated by Brandes and Coons (*1*) in the case of sugar beets, to the effect that beets are best and most profitably grown in those temperate regions wherein the mean summer isotherm lies between 67° and 72° F.

Apparently relatively few attempts have been made to study the effect of temperature on the rate of growth of the sugar beet. Tavernetti (**6**) found, however, that under California conditions relatively little weight accumulated until minimum soil temperatures ranged above 55°. In 1944 the authors presented a preliminary study of this problem to the society (*4*). As result of these studies, a further investigation was instituted in 1945, with the hope of obtaining somewhat more specific information on the growth of the beet root as it responds to seasonal variations in temperature. The present report must be considered as one of progress only, since it is based on results of only 1 year.

Materials and Methods

The field used was located about 4 miles west of Billings, Mont. Here uniformity was good and cultural practices were of the highest order; the yield of approximately 16 tons per acre was somewhat above average for the factory district.

One thermograph was exposed in a standard instrument shelter 4 feet above ground and another in a similar shelter set directly on the ground with the recording element 3 inches above the surface and immediately adjacent to one row of beets. A soil thermograph was also housed in this ground shelter, with the bulb buried between two rows at a depth of 8 inches. Weekly readings at 2-inch depth were also made by means of thermometer and/or thermocouple, the latter read by use of the conventional Wheatstone bridge.

To obtain information as to the weekly increase in size of the root, a simple arrangement involving use of a test tube, 5-inch length of small laboratory glass tubing, and a piece of oiled-silk fish line about

[1]Meterologist in charge, United States Weather Bureau, Billings, Mont., and Associate Agronomist, Great Western Sugar Company.

[2]Italic numbers in parentheses refer to literature cited.

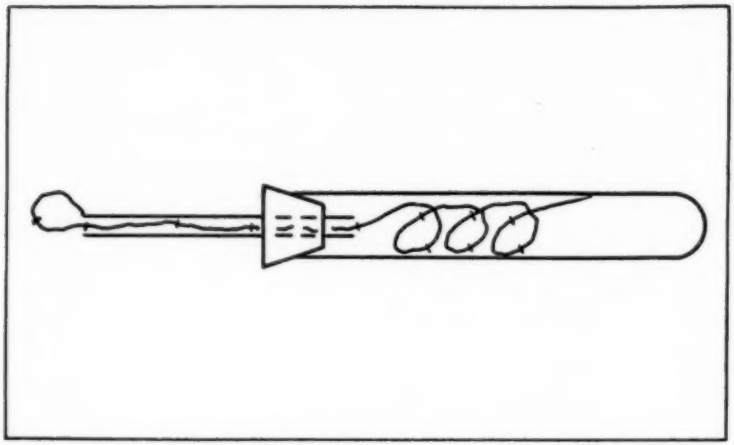

Figure 1.—Apparatus used for circumference measurements of beets.

2 feet long was designed. A sketch of this device is shown as figure 1. The line was marked off in inches with india ink and fastened to the extreme outer end of the glass tubing. It was then extended around the root at the maximum diameter, up through the glass tube, and into the test tube where the excess was coiled. Readings were made with reference to an index mark etched in the glass tube 2 inches from the end.

Information was had verbally that Swedish investigators had made a device for a similar purpose, but the instrument was not obtained.

Twenty-seven beets were selected at random to serve for measurements, and the apparatus shown in figure 1 was applied. The procedure followed throughout the season was to take circumference readings on all 27 beets each Saturday noon and at the same time change thermograph sheets and make check readings and such other measurements as were needed. Sunshine, wind direction and velocity, rainfall, and cloudiness data were recorded at the United States Weather Bureau office 5 miles due north of the test field. This equipment was installed quite late in the season—June 28—because of delay in receiving some of the instruments needed. The roots at that time averaged about one and one-fourth inches at the major diameter. The last week of record ended on September 29 when the field was harvested.

Results

The general relation which was found to exist between temperature and weekly increments in root size is shown in figure 2.

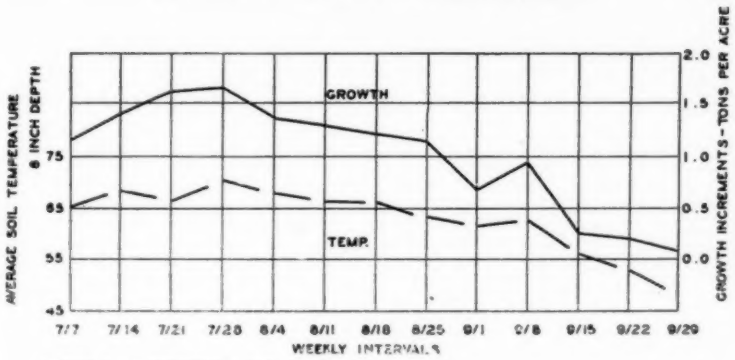

Figure 2.—Temperature and growth-rate curves.

Shown here are weekly increases in the circumference of roots translated into terms of tons per acre, and weekly averages of the soil temperature at the 8-inch depth. Smith (*5*), working at Jerome, Idaho, found a circumference-weight ratio of 6.57. Data taken in this study give a ratio of circumference to weight of 6.36. All things considered, this shows very good agreement.

Soil temperature was selected for correlation with growth only after making a large number of comparisons, including maximum, minimum, and average at the 2-inch and 4-foot levels, frequency of specific temperature levels, a degree-day type of summarization with a 45° base, and a heat unit summarization involving adjustment and weighting of temperature values according to their frequency of occurrence. Eight-inch average soil temperature proved to show a higher correlation with growth than did any of the other factors. The parallelism between the two curves shown in figure 2 is quite striking; in fact the direction of change from week to week was the same except in one instance, that of July 21 when the deficiency of sunshine hours resulted in a depressed soil temperature. It is interesting to note that there was a rise, both in temperature and growth rate, during the first week of September when the general trend of the seasonal curve was downward.

In figure 3, soil temperature and growth rate have been plotted in the form of a scatter diagram. So far as the 1945 season is concerned at least, this represents the relationship between rate of growth and soil temperature. The curve shown is simply a free-hand fitting of the data by the method of Ezekiel (*2*), since no satisfactory regression equation for the line has yet been derived. However, the index of correlation computed for this curve is 0.970, a figure considerably above the 1 percent level of significance (0.684). The lower end of this curve would, if extended, reach zero at about 40° F., which appears reasonable, and its steepest slope occurs between 60° and 65°

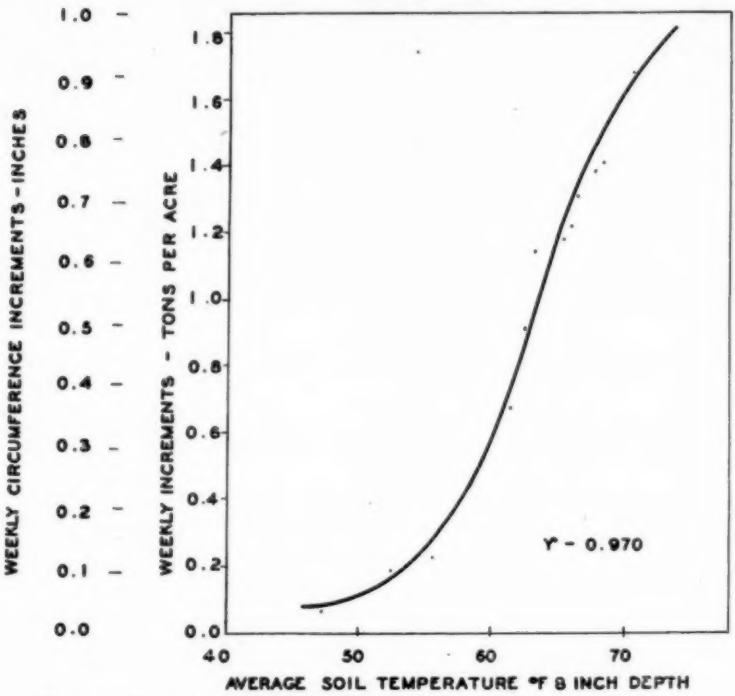

Figure 3.—Seasonal growth rate curve.

F. While the upper end of the curve is shaped to suggest a maximum value somewhere in the seventies, the data do not form any basis for fixing the optimum. The highest weekly temperature of 70.8° occurred during the week of July 28 and in all likelihood is below the optimum. It would be most valuable to know just where this maximum value lies, but since averages much above 70° seldom occur in the Billings area it seems unlikely that it can be determined without resorting to artificially controlled conditions.

It will be noticed that weekly increments used in figures 2 and 3 are given in terms of tons per acre increase. Conversion from circumference increase was made on the basis of the ratio between final circumference and weight. It was found that an increase of 1 inch in circumference yielded an average of .157 pounds in weight. Using, then, 23,760 as the number of plants per acre, with 22-inch rows, the figures used as weekly increments in tons per acre were obtained. Figure 4 shows the relation between circumference and weight for each of the 27 roots measured. The relationship is approximately linear, and scattering was due mainly to differences in the shape of

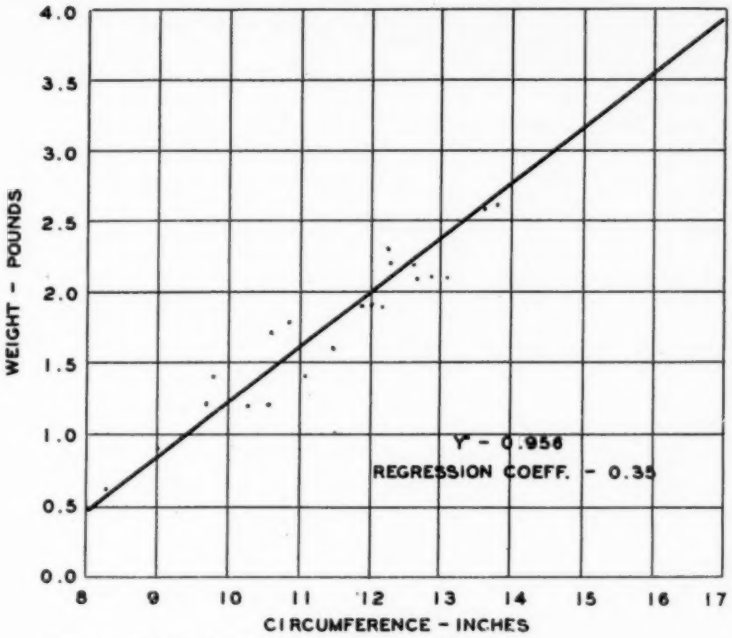

Figure 4.—Relation of weight to circumference (27 roots).

individual roots. Strictly speaking, weight increment per unit increase in circumference varies with the size of the root, and the relationship shown in figure 3 applies accurately only to the scale of circumference increase shown. However, for the purpose of this paper, these figures have been converted into terms of tons per acre, since these have more practical significance and the error is small.

One of the explanations which seems to account for the superiority of soil over air temperature as an index of the growth rate is that the roots grow in the soil rather than in the air. This may be physiologically important; but a more logical explanation is the fact that the soil tends to act as an intergrating mechanism—through which changes in air temperature, sunshine, relative humidity, wind and all other weather factors, operative in the free air, are combined. Increases in air temperature and sunshine, for example, result in corresponding increases in soil temperature. A rise in the rate of evaporation, and the application of moisture, either as rainfall or irrigation water, on the other hand, tends to cool the soil. Thus, changes in all weather factors are additive in their effect upon the warmth of the soil, which in turn has its effect upon chemical and biological processes going on in support of growth.

Summary

No definite conclusions can or should be drawn from the preliminary information presented. Certain indications may be pointed to, however, as follows:

1. In a pre-harvest estimate of yields, the influence of the seasonal temperatures might beneficially be taken into account.

2. It is shown that there is a strong correlation between the soil temperatures and rate of growth of sugar beets in this area; that such soil temperature may be the best index of the influence of various climatic factors on the growth of the sugar beet in that it may act as a medium of integration for several environmental forces.

3. As pointed out by Tavernetti (*6*) the soil temperature can have considerable bearing on when to apply commercial fertilizers, in order to have available a plentiful supply of plant food at the time most needed by the plant in rapid growth.

Meteorological Notes

1. Contrary to expectations it is noticeably warmer in the afternoon at the 4-foot level than near the ground. This is due, apparently to the cooling effect of growing plants. Similarly the lowest night temperatures were found, not at the ground level, but in the 4-foot shelter.

2. Leaf temperatures, as accurately as could be measured, were found to be 4 to 5 degrees lower on warm sunny afternoons than that of the surrounding air due, of course, to transpiration. This is true in spite of the dark color of the leaves, which should increase their capacity for absorbing heat.

3. The average seasonal temperature of the soil was about 1 degree lower than that of the air. This can be accounted for by evaporation of moisture from the soil surface.

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The Effect of Climate on Sugar Beet Yields In Western Montana

EDWARD L. SWIFT and FRANK A. CLELAND[1]

The relationship of climate and its effect on the sugar beet crop has received attention and study by a number of workers in this country. As far as temperature is concerned, the sugar beet can grow in any state of the United States. In general, however, the sugar beet makes its best and most efficient growth as a crop plant in the United States within a zone lying between the summer temperature isotherms of 67° and 72° F. Wiley (*4*) called attention to this relationship and in 1901 mapped the potential belt of sugar beet culture in the United States. It is of interest to note that in the years that followed this generalization the actual localization of the industry tallied rather closely with the predicted areas best suited for the sugar beet crop. Brandes and Coons (*1*)[2] expressed the opinion that summer temperatures affect the production and quality of sugar beets less than does the water supply. Pierce et al (*2*), working under eastern Montana conditions, found an interesting but not highly significant correlation between June temperatures and acre yields of beets. Tavernetti (*3*), in making a study of beet growth and response to fertilizers, found that under California conditions the growth increment was small when minimum soil temperatures were less than 55° F.

In western Montana certain trends in weather and yield of beets have been observed, leading to the belief that yield might be associated with daily temperatures. To test this inferred relationship as a possible basis for predicting beet yields, a study was made of climatological data available for this western Montana area, and results of this study are reported herein.

The poorest beet crop in the 17 years the Missoula factory has operated was harvested in 1943. The sugar-per-acre yield was 700 pounds below the average of the preceding crops. A record amount of snow had fallen during the winter, with lower than average temperatures. The Spring was late, cold, and wet, the planting was delayed, and thinning and cultivating was later than normal. The results of this growing season led to a preliminary survey of the effects of weather on beet yields. All of the data available on length of growing season, annual precipitation, average annual maximum and minimum temperatures, and average mean temperature were studied in relation to the yield of beets and sucrose percentage for the 11-year period, 1933 to 1943 inclusive. This study was continued in 1944 and

[1]Agriculturist and Manager, respectively, American Crystal Sugar Company, Missoula, Mont.

[2]Italic numbers in parentheses refer to literature cited.

1945, and after various analyses of the data had been made it became apparent that for the 13 years it would be necessary to begin with October weather data of each year for studies of effects on the beet yield of the subsequent year. This is reasonable, since weather after the first of October does have an influence on the following growing season. Moisture falling this quarter is carried over. If there is a warm Fall, bacterial action is stimulated and fertility of the land is increased. Also, an open Fall permits completion of Fall plowing operations which contributes appreciably to increased crop yields.

Temperature Effects

The effect of average daily mean temperatures on beet yield is most striking, as is shown in the graph in figure 1.

The highest annual mean temperature was 49.4° in 1940, and the lowest was 44.9° in 1943. This is a variation of only 4.5° in annual

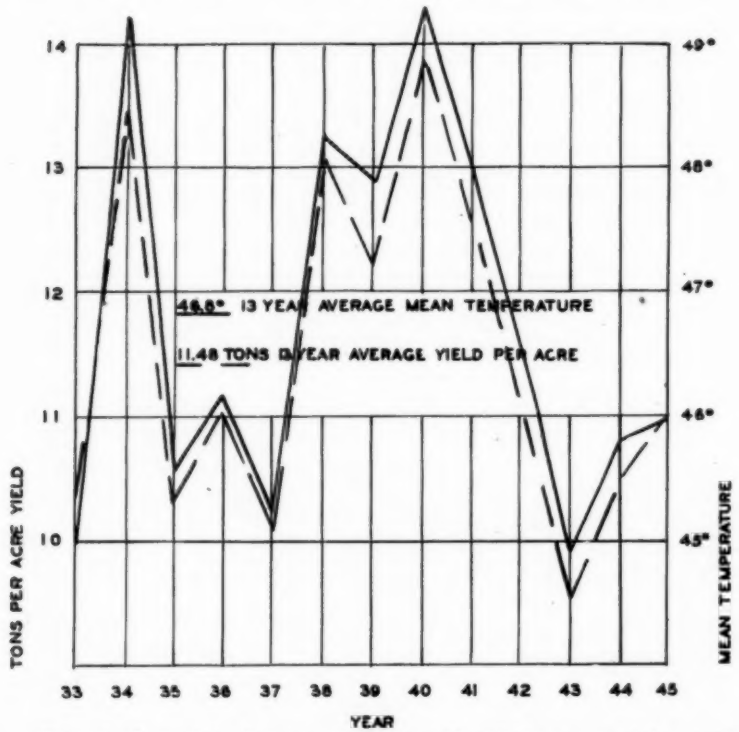

Figure 1.—Comparison of average sugar beet yields with the average of the annual mean temperatures for the 12-month period, October through September, 1933 to 1945.

mean during the entire 13-year period. As to beet yields, the highest tonnage produced was in 1940 with 13.96 tons beets per acre, and the lowest was in 1943 with 9.52 tons per acre. The variation in yield per acre for the 13 years was 4.44 tons. The relationship between annual mean temperature and beet yield is very apparent. In no year does the yield fluctuate widely from the annual average mean. Increases or decreases of 1° in annual mean temperature have a direct effect on the yield of beets. Thus each degree variation from the average is responsible for an increase or decrease of 1 ton of beets per year.

In breaking down this relationship of mean temperature to beet yields, the data were arranged in October through December, October through March, and October through June categories, in addition to the October through September grouping shown in figure 1. The resultant data indicated a sufficiently close correlation to permit the deduction as early as January that the first quarter average of daily mean temperature is usually following the same trend it will follow for the entire season. Further, by using the 6 months' average mean temperature reading of October through March, it is possible before the crop is planted to have a fairly reliable estimate of what the crop will yield. By using the 9 months daily average mean temperature, it should be possible to estimate yields within ½ ton per acre.

A similar study was made for temperature effects upon sucrose, and a negative relationship was obtained, as is shown in figure 2.

The graph in figure 2 shows that as a rule high mean temperatures were reflected in lower sucrose content, and low mean temperatures were generally productive of higher sucrose content in beets. From the graph, the year 1943 was an exception to this because of excessively high precipitation which affected adversely both tonnage yield and sucrose content in the beet.

Effect of Precipitation

Figure 3 is a comparison of sugar beet yields with total annual precipitation. This graph shows a very definite trend in the effect of precipitation on beet crops.

These data show that for the 13-year period better beet crops were produced when precipitation was above the 12.60-inch average annual rainfall; and further, that more than 16 inches of moisture per year had an adverse effect on yield under western Montana conditions. Considering the fact that this area has an abundance of irrigation water, too much rainfall is more detrimental to crop growth than too little rainfall, because of increased weed growth and the deterrent effect on performance of timely cultural and other farming operations.

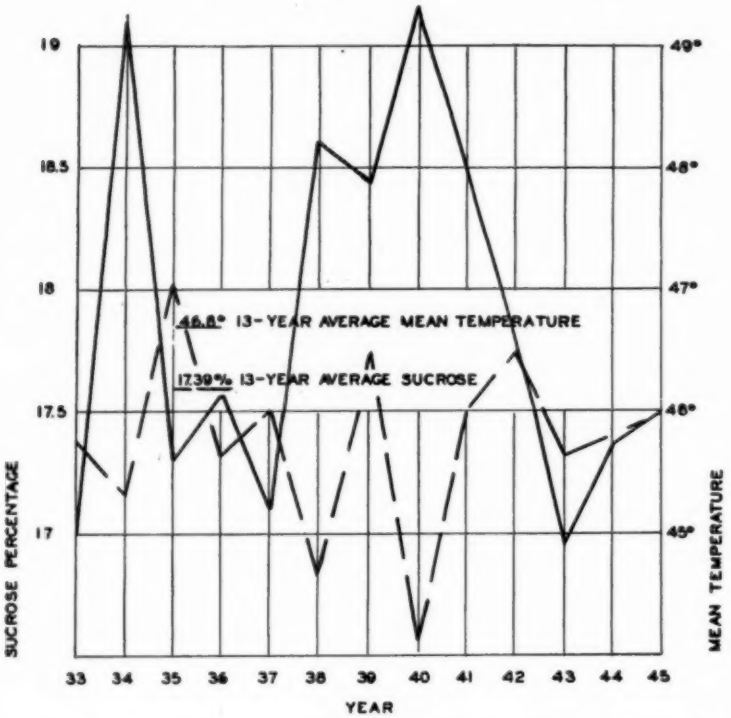

Figure 2.—Comparison of the average sucrose percentage with the average of the daily mean temperatures for the 12-month period, October through September, 1933 to 1945.

Estimating Yields by Using Mean Temperatures

Since the temperature-yield relationship seemed to be the most reliable, an attempt was made in early October of 1944 to estimate the yield of the crop on the basis of the mean temperature for the past 12 months. The estimate was 10.25 tons per acre, which was .25 tons short of the actual yield of 10.50 tons per acre. In July of 1945 a prediction of that year's crop was made. The figure of 11.00 tons per acre was obtained by using the mean temperature for the previous 9-month period. Adding to this another .50 ton to compensate for the increased yield because of the recently developed practice of side-dressing beets with nitrogen, the expected yield was 11.50 tons per acre. (About 1/3 of the acreage was side-dressed with nitrogen fertilizer, which we expected to increase the yield by 1½ tons per acre, or ½ ton per acre for the entire acreage.) Early in October a final esti-

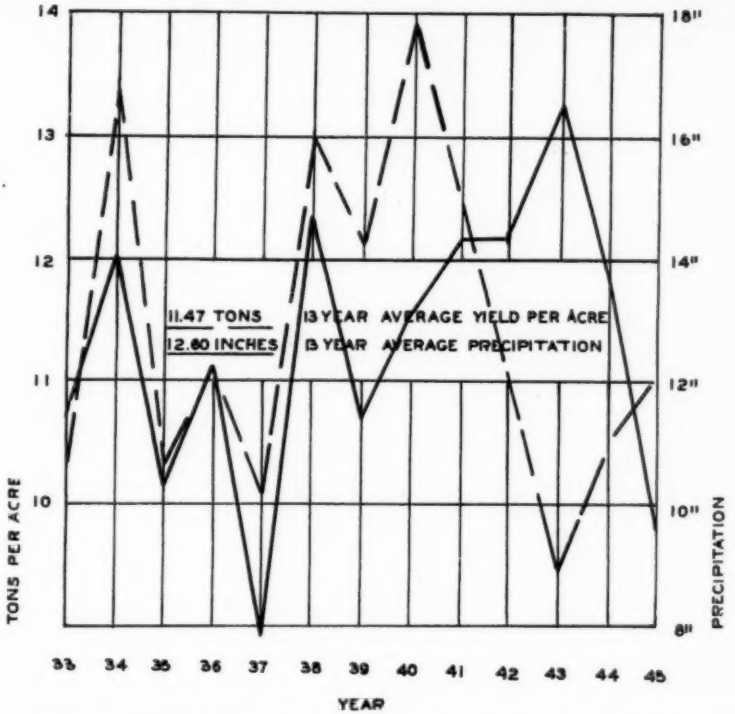

Figure 3.—A comparison of sugar beet yields with annual precipitation for the period October through September, 1933 to 1945.

mate was made on the basis of 12 months' elapsed annual mean temperatures. The yield estimate was 10.70 tons per acre, plus the .50 tons expected increase from the use of nitrogen, or 11.20 tons beets per acre. The actual yield was 11.02 tons per acre.

From the data obtained to date, it is felt that it may be possible in the future to predict the amount of additional nitrogen that will be needed by the sugar beet crop during the growing season. If a warm season is predicted, the amount of additional nitrogen required would be less, because soil bacteria would convert more nitrogenous organic matter into nitrates available to the plant. A cold season would demand additional nitrogen, side-dressed in an available form to meet the requirements of a normal crop of beets.

Summary

The average of October through September daily mean temperature readings in western Montana is closely related to beet yields, with each degree annual variation producing approximately 1 ton difference in beet yields.

Sucrose percentages are generally lower when the annual mean temperature is high.

Annual rainfall is also associated with yield but not to the same extent as mean temperature.

An October 1 estimate of beet yields based on the annual mean temperature for 1944 was .25 tons short of the actual yield. By use of the average daily mean temperature from October through June, 1945, in early July it was possible to estimate the yield within .50 ton; and in early October, 1945, within .25 ton.

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Four Years' Results of Pre-Harvest Sampling in Estimating Yield and Sugar Percentage

H. E. Brewbaker and H. L. Bush[1]

In preparation for a processing campaign, a fairly precise estimate of the tonnage of beets to be harvested and the sugar to be processed is highly important to the management of a sugar beet company.

Previous to 1941, harvest estimates for the Great Western Sugar Company were based on samples chosen by the fieldmen in each factory district from a few farms without any prescribed plan being used. For the 1941 season a plan based on random sampling technique was designed and initiated, with results indicating considerable improvement in precision over previous methods. (*1*)[2]

The general method as based on random sampling technique has been continued to date with a few changes as to details. Complete results for the years 1941 to 1944 are included in this study.

Methods Used

Contracts smaller than 5 acres were not eligible for sampling because the contracts of such size were few in number and their total constituted a very small part of the gross acreage. The total acreage included in the contracts from 0-5 acres amounted to 1.3 percent of the total as an average of four factory districts taken more or less at random. All contracts of 5 acres or over were numbered and those to be sampled chosen by lottery. In 1941 all contracts with previous yield records of 3 consecutive years were stratified into five yield classes, a similar number of contracts being chosen from each class. Because a possible bias was recognized in the 1941 method due to the exclusion of certain contracts not having previous consecutive yield records of 3 years, a geographic method of stratification and sampling by fieldman districts was used in 1942 and 1943 and by dump districts in 1944.

In 1941 two samples were taken from the same field for each 100 acres, the basis being changed to one sample per each 90 acres since 1941.

The number of contracts sampled for each factory for each year is shown in table 1.

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[1]Director and Statistician-Agronomist, respectively, Experiment Station, Great Western Sugar Company, Longmont, Colorado.

[2]Italic numbers in parentheses refer to literature cited.

Table 1.—Number of contracts sampled.

Factory	1941	1942	1943	1944
Colorado				
Eaton	120	179	111	120
Greeley	100	128	83	80
Windsor	80	117	83	87
Fort Collins	90	137	90	87
Loveland	75	114	84	71
Longmont	90	169	137	112
Brighton	61	110	87	61
Fort Lupton	65	138	101	90
Ovid	115	201	146	117
Sterling	100	156	103	88
Brush	62	91	68	71
Fort Morgan	99	183	105	104
Colorado total	1,057	1,723	1,198	1,088
Nebraska				
Scottsbluff	....	135	70	77
Gering	....	117	72	72
Bayard	85	139	86	81
Minatare	....	73	57	53
Mitchell	45	88	51	69
Lyman	50	78	55	67
Nebraska total	180	630	391	419
Montana				
Billings	....	295	202	227
Wyoming				
Lovell	80	112	52	62
Grand total	1,317	2,760	1,843	1,796

The sampling unit which consisted of exactly 10 feet of row remained the same throughout the 4 years, the location being chosen on an arbitrary pre-arranged basis so that the fieldman had no choice in taking the sample. In case the contract selected for sampling included more than one field, the larger field was sampled. In 1941 two samples of 10 feet of row were taken for each field chosen for each of two dates of sampling, from which the error per sample was determined. After 1941 only one sample was taken from each field. To determine the location of the sample, the fieldman was directed to enter the field at the "nearest corner" and count over a specified number of paces to the beginning of the sample. If the beginning or the end of any sample centered on a beet, the decision as to whether or not it would be included in the sample was made by flipping a coin. All beets over 1 inch in diameter were topped according to tare standards, placed immediately in water-proofed bags, and later washed, counted, weighed, and tested for sugar.

For the second date of sampling, which was 2 weeks after the first, the sample location was 10 feet beyond the first in the same row.

Harvest stand figures were obtained from tare samples taken at frequent intervals for each contract, the average weight per beet for these samples and the total tonnage for the contract being used for this calculation.

Results

From the 1941 data (*1*) for 16 factory districts an increase in precision of 14 percent in tonnage of roots was obtained with 2 samples per field as compared with 1 sample. On the basis of one sample per field the number of acres per sample to secure various levels of accuracy per factory district was as follows:

Levels of accuracy tons roots per acre	Acres per sample
±0.5	9
±1.0	36
±1.5	80
±2.0	144
±2.5	228

A ±1.5 tons level of accuracy per factory, requiring 80 acres per sample, would have resulted in an approximate accuracy for an average of 20 operating Great Western factories of $1.5 \div \sqrt{20}$ or about ±0.34 tons of roots per acre.

The relative precision of stratification for 1941, 1942, and 1944, representing respectively the three methods used, viz., by previous 3-year yield records, fieldman districts and dump districts, is summarized for yield of beets with corresponding number of strata for the various factory districts in table 2.

The precision for 1943 was not determined, since it represents the same form of stratification used in 1942. For complete data and the statistical method used to test precision, see reference 1. The variance for percentage of sugar was not calculated, since this character is considerably less variable than yield of roots.

The precision due to stratification (table 2) was calculated in percentage of complete randomization considered as 100. There is a certain amount of bias in these precision figures since the samples as taken, with the limitations imposed due to stratification, were used to calculate the error without stratification. The same total error of sampling has been assumed for both cases. The bias in making this assumption is probably too small to be of any practical significance.

There is also an additional bias for the method as used in 1941, since not all farms were eligible to be included in the lottery, which excluded all contracts (all new beet growing farms and those which

Table 2.—Relative precision of stratification in percentage of complete randomization and number of strata.

Factory	1941[1]		1942[2]		1944[3]	
	Strata No.	Precision Percent	Strata No.	Precision Percent	Strata No.	Precision Percent
Colorado						
Eaton	5	115.68	5	106.55	11	101.99
Greeley	5	104.09	4	100.49	9	97.07
Windsor	5	118.07	3	98.43	9	102.93
Fort Collins	5	109.09	4	105.82	15	100.37
Loveland	5	118.18	3	109.41	14	92.69
Longmont	5	112.08	6	105.06	27	96.73
Brighton	5	107.50	3	99.99	13	90.79
Fort Lupton	5	127.01	3	99.76	13	110.25
Ovid	5	104.09	6	116.86	18	108.14
Sterling	5	105.97	4	104.86	15	109.60
Brush	5	98.75	2	98.89	13	100.21
Fort Morgan	5	118.46	5	109.74	14	101.71
Colorado average	....	111.58	....	104.66	....	100.97
Nebraska						
Scottsbluff	....	....	6	103.80	9	115.46
Gering	....	....	4	119.93	10	120.06
Bayard	5	108.16	4	98.71	17	119.53
Minatare	....	....	3	98.48	5	111.37
Mitchell	5	108.07	2	100.10	7	104.81
Lyman	5	122.18	2	99.55	7	115.00
Nebraska average[4]	....	112.80	....	99.45	....	113.11
Nebraska average[5]	....	....	....	103.43	....	114.37
Montana						
Billings	....	....	8	102.89	36	113.95
Wyoming						
Lovell	5	118.56	4	108.15	11	106.07
Colorado-Nebraska average[4]	....	111.83	....	102.92	....	103.39
G. W. S. Co. average[4]	....	112.25	....	103.20	....	104.17

[1]Stratified according to previous yield records
[2]Stratified according to fieldman districts
[3]Stratified according to dump districts
[4]Averages for only those factories represented 3 years
[5]1942-1944 average

may have been temporarily out of beet production), without a consecutive 3-year previous record. The precision based on stratification by the previous 3-year yield record amounted to 112.23 percent as an average for 16 factories in 1941, while the precisions using the geographic methods of stratification for 1942 and 1944 were 103.20 percent and 104.17 percent, respectively, as averages for the same 16 factories. The increase in precision due to stratification for the 1941 results is somewhat higher than for either 1942 or 1943. The geographic distribution of the samples, however, was not as complete

in 1941 as for either of the other 2 years and, for this reason, it is entirely possible that the pre-harvest estimates for the later years constitute more accurate indices of the true yield situation.

It will be observed from the number of strata used in 1944 that many units ("dumps") were involved in the stratification, in which case some strata were represented by only one or two samples, particularly for several factories in Colorado. Precision was lost for several such factories by this geographic restriction as compared with complete random sampling, the method being somewhat less efficient for those factories than either of the other stratification methods. For the factories in Nebraska, however, geographic stratification by dump districts in 1944 appeared to be somewhat more efficient than by fieldman districts as in 1942, being equal to the method used in 1941.

The results for percentage of stand, yield of beets, and percentage of sugar are presented for the 4 years 1941-44 in tables 3, 4, and 5, and also are summarized for Colorado, Nebraska, and Great Western averages in table 6. The results for yield of roots and percentage of sugar are graphically presented in figures 1 and 2, respectively.

In stand (table 3) a slight loss is indicated in most cases for the 2-weeks period between samplings. This condition seems to be too consistent to be due to random error, but there seems to be no reason-

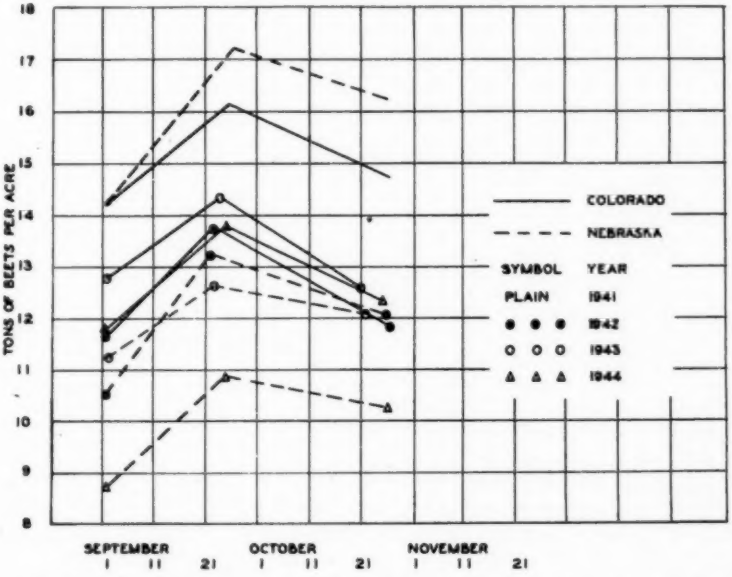

Figure 1.—Sample estimates and final results for tons beets per acre for farms sampled.

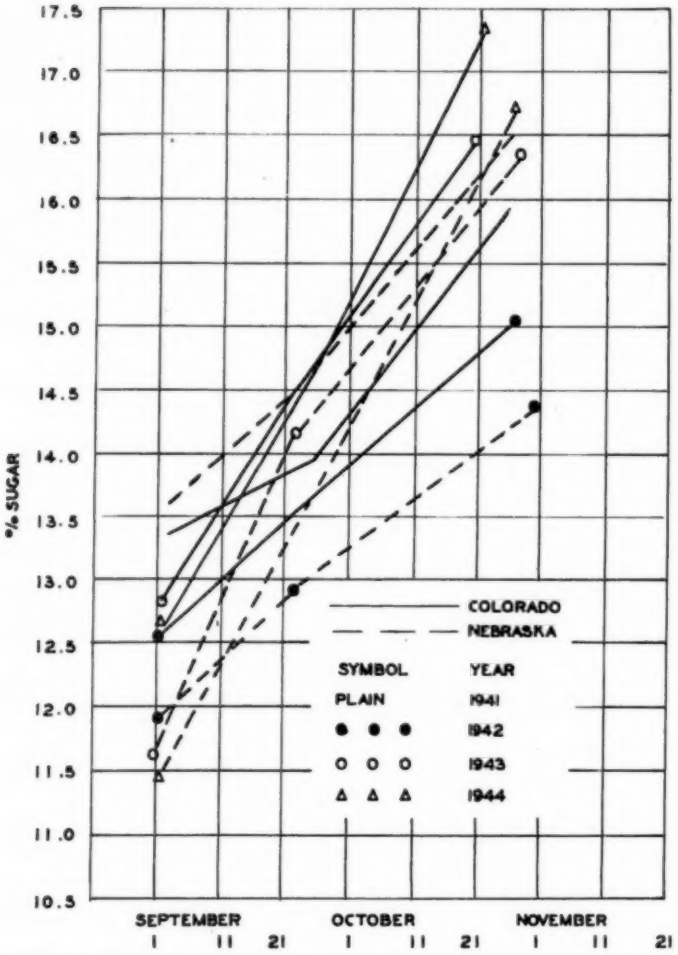

Figure 2.—Sample estimates of final results for percentage sugar for farms sampled.

able explanation for a loss of even this magnitude. The loss between pre-harvest samples and harvested stand for the contract is considerable and may be at least largely accounted for by (1) beets left in the field or dropped from trucks in delivery, (2) small beets returned at the piler in the tare, (3) some loss from root rots, (4) weak stands at the ends of the rows which were not included in the sampling, and (5) some breakage at the piler with the net result that broken pieces in the tare sample may not have been counted.

tory harvest averages.

Factory	1941 Farms sampled 1st	1941 Farms sampled 2nd	1941 Farms sampled Harv.	1941 Factory ave.	1942 Farms sampled 1st	1942 Farms sampled 2nd	1942 Farms sampled Harv.	1942 Factory ave.	1943 Farms sampled 1st	1943 Farms sampled 2nd	1943 Farms sampled Harv.	1943 Factory ave.	1944 Farms sampled 1st	1944 Farms sampled 2nd	1944 Farms sampled Harv.	1944 Factory ave.
	Percent				Percent				Percent				Percent			
Colorado																
Eaton	94	92	77	79	83	82	66	66	82	79	72	71	76	74	61	61
Greeley	91	87	78	80	75	77	65	68	86	87	67	70	70	80	58	60
Windsor	82	86	76	75	84	87	68	66	87	87	72	73	78	77	61	59
Fort Collins	88	87	79	80	83	79	66	69	81	77	66	70	71	69	58	58
Loveland	92	90	81	86	85	86	74	76	86	88	76	78	75	73	56	59
Longmont	97	93	85	84	88	87	74	78	83	83	72	71	74	71	61	64
Brighton	97	91	83	79	95	88	75	71	86	82	66	68	70	70	59	61
Fort Lupton	88	90	81	82	86	86	70	73	83	82	69	73	72	72	61	59
Ovid	90	88	73	75	84	87	63	68	84	83	66	74	71	69	56	56
Sterling	87	88	81	82	81	82	65	67	85	82	70	71	65	68	56	61
Brush	86	84	70	73	71	73	63	64	87	88	68	68	72	68	57	57
Fort Morgan	88	86	77	73	79	75	61	65	83	80	63	66	71	69	56	55
Colorado ave.[1]	90.1	88.6	78.3	78.9	82.9	82.5	67.0	86.5	84.3	83.1	68.9	70.4	72.2	71.4	58.4	59.2
Nebraska																
Scottsbluff	....	....	....	....	82	81	65	67	92	88	66	69	77	73	61	64
Gering	....	....	....	....	17	78	65	62	85	84	67	64	63	64	51	53
Bayard	82	82	70	72	77	78	62	65	73	71	57	59	64	61	51	53
Minatare	....	....	....	....	91	89	62	62	86	83	63	62	63	61	51	51
Mitchell	83	79	70	71	71	73	63	65	73	72	63	66	62	66	53	56
Lyman	92	89	74	74	76	77	59	60	93	90	67	65	74	74	59	61
Nebraska ave.[1]	85.0	83.2	71.1	72.3	79.1	79.3	62.9	63.1	83.4	80.9	63.5	63.2	67.4	66.6	54.4	56.5
Montana																
Billings	....	....	....	....	97	94	74	77	90	89	68	70	79	76	59	62
Wyoming																
Lovell	100	97	74	71	93	95	68	69	84	87	62	62	87	89	69	66
Colorado-Nebraska ave.[1]	89.4	87.8	77.3	77.9	81.9	81.6	65.9	67.0	84.1	82.6	67.1	68.6	70.6	69.8	57.1	58.3
G. W. S. Co. ave.[1]	91.5	88.3	77.0	77.5	83.9	83.5	66.9	68.2	84.7	83.4	66.9	68.6	71.8	71.1	57.8	58.9

[1]Averages weighted according to number of farms sampled in each factory.

Table 4.—Yield of beets in tons per acre as obtained from pre-harvest samples (1st and 2nd) and contract deliveries in comparison with factory harvest averages.

Factory	1941				1942				1943				1944			
	For Farms Sampled			Factory ave.	For Farms Sampled			Factory ave.	For Farms Sampled			Factory ave.	For Farms Sampled			Factory ave.
	1st	2nd	Harv.		1st	2nd	Harv.		1st	2nd	Harv.		1st	2nd	Harv.	
Colorado	Tons per Acre				Tons per Acre				Tons per Acre				Tons per Acre			
Eaton	16.13	17.28	16.02	16.43	12.70	14.55	13.20	12.96	14.73	16.49	14.57	14.91	13.61	15.83	14.86	14.55
Greeley	14.90	15.50	14.58	14.38	11.64	13.56	11.44	11.93	13.10	14.62	12.27	12.76	11.41	13.55	12.58	12.54
Windsor	15.13	17.94	15.63	16.03	13.95	16.51	13.82	13.62	16.04	17.78	14.98	14.51	14.29	15.36	14.22	14.55
Fort Collins	12.58	14.43	13.49	13.33	10.66	12.35	10.53	10.77	12.31	13.33	11.67	12.48	11.49	13.65	11.77	11.70
Loveland	13.16	14.53	13.86	13.78	12.02	15.14	12.94	13.48	13.26	14.70	13.50	13.20	11.22	13.30	13.13	13.64
Longmont .	14.71	16.35	14.87	14.60	12.41	14.49	12.83	13.30	13.77	15.56	13.24	13.35	11.63	13.38	12.17	12.88
Brighton	13.70	15.52	15.00	14.67	12.55	13.61	11.32	11.37	11.63	13.05	11.35	11.76	10.65	12.11	11.38	11.55
Fort Lupton	14.43	16.77	15.35	15.42	11.25	12.85	11.48	11.68	12.65	14.43	13.20	13.52	11.77	12.19	12.16	11.74
Ovid	13.03	15.60	13.39	13.35	9.56	13.28	10.43	10.92	9.47	11.92	10.26	10.67	10.17	13.14	10.71	10.95
Sterling	12.55	14.92	13.92	14.13	11.00	12.86	11.01	11.06	11.19	13.16	11.28	11.33	8.73	11.81	10.09	11.00
Brush	15.58	17.42	14.54	15.59	9.55	11.32	9.45	9.96	13.18	14.60	12.89	13.27	14.05	15.82	13.47	13.12
Fort Morgan	15.45	17.29	16.73	15.90	12.64	13.71	12.12	12.42	13.08	14.32	12.30	12.91	12.97	15.56	12.76	13.08
Colorado ave.[1]	14.29	16.11	14.78	14.79	11.65	13.71	11.75	11.99	12.73	14.42	12.54	12.81	11.82	13.88	12.46	12.63
Nebraska																
Scottsbluff	....	....	....	....	10.98	13.33	12.43	12.83	13.00	14.42	13.72	13.87	12.32	14.44	12.68	12.90
Gering	....	....	....	....	12.24	15.34	14.07	14.12	9.89	12.08	12.22	12.35	7.14	9.87	9.20	9.41
Bayard	12.00	16.10	14.83	14.70	9.46	11.72	11.24	11.71	8.09	9.03	9.25	10.09	7.86	9.52	9.63	10.04
Minatare	....	....	....	....	13.23	16.71	12.92	12.50	13.40	15.03	13.02	12.33	8.14	10.03	9.65	9.71
Mitchell	15.30	17.74	17.36	17.39	10.20	13.13	11.76	12.25	12.29	13.68	12.63	13.56	7.87	10.21	9.64	10.35
Lyman	15.35	18.52	17.69	17.95	7.28	10.05	9.29	9.68	12.58	13.33	12.96	13.14	8.71	11.57	11.17	11.93
Nebraska ave.[1]	14.23	17.18	16.26	16.28	10.57	13.31	12.05	12.31	11.25	12.64	12.11	12.39	8.73	10.99	10.37	10.77
Montana																
Billings	....	....	....	....	12.46	14.90	12.86	13.47	11.10	12.56	10.81	10.91	9.54	13.13	10.20	10.47
Wyoming																
Lovell	15.24	16.45	13.11	13.13	10.70	12.76	10.80	11.23	11.42	14.00	11.22	11.20	11.76	15.10	12.38	12.20
Colorado-Nebraska ave.[1]	14.28	16.27	15.00	15.01	11.36	13.60	11.83	12.08	12.37	13.98	12.43	12.71	10.80	12.92	11.76	12.01
G. W. S. Co. [1]ave.	14.34	16.28	14.88	14.89	11.45	13.71	11.90	12.19	12.20	13.83	12.22	12.47	10.78	13.04	11.72	11.94

[1]Averages weighted according to number of farms sampled at each factory district.

Table 5.—Percentage of sugar as obtained from pre-harvest samples (1st and 2nd) and fave sampling for contracts sampled in comparison with factory harvest averages.

	1941	1942	1943	1944

ave.	14.34	16.28	14.88	14.89	11.45	13.71	11.90	12.19	12.20	13.83	12.22	12.47	10.78	13.04	11.72	11.94

[1]Averages weighted according to number of farms sampled in each factory district.

Table 5.—Percentage of sugar as obtained from pre-harvest samples (1st and 2nd) and late samples for contracts sampled in comparison with factory harvest averages.

	1941				1942				1943				1944			
	Farms Sampled			Factory	Farms Samp'ed			Factory	Farms Samp'ed			Factory	Farms Sampled			Factory
Factory	1st	2nd	Harv.	ave.	1st	2nd	Harv.	ave.	1st	2nd	Harv.	ave.	1st	2nd	Harv.	ave.
Colorado			Percent				Percent				Percent				Percent	
Eaton	13.2	13.9	16.0	16.0	12.5	13.3	13.9	14.0	12.4	14.7	16.8	16.8	12.3	14.6	18.2	18.2
Greeley	13.7	14.4	16.1	16.2	13.4	13.9	14.7	14.8	13.1	15.3	16.6	16.7	13.5	15.9	17.8	17.9
Windsor	12.6	13.8	16.0	16.0	13.2	13.9	14.7	14.8	13.1	14.6	16.4	16.3	12.8	14.9	17.8	17.8
Fort Collins	12.5	14.2	16.1	16.0	13.1	13.8	14.6	14.8	13.1	15.1	17.3	17.0	13.1	15.4	18.1	18.0
Loveland	13.4	14.2	16.0	16.1	13.3	14.3	16.0	16.0	13.2	15.0	16.8	16.5	13.2	15.1	17.5	17.5
Longmont	14.3	14.4	16.1	16.2	13.5	14.1	16.5	16.5	13.3	14.6	16.4	16.5	13.6	15.3	17.9	18.0
Brighton	14.5	14.6	17.0	16.8	13.7	13.9	15.7	15.7	13.4	15.1	17.4	17.4	13.2	15.2	18.3	18.2
Fort Lupton	14.1	14.6	16.7	16.7	13.5	13.9	15.7	15.7	13.3	14.8	16.9	16.8	13.4	14.8	17.8	17.7
Ovid	13.0	12.7	15.1	15.1	11.2	12.3	15.2	15.1	11.8	13.8	16.1	16.1	11.2	13.1	16.5	16.5
Sterling	13.2	13.8	15.7	15.7	12.3	13.6	14.4	14.3	12.4	14.1	16.0	15.9	12.2	14.2	16.8	16.6
Brush	12.8	12.8	15.8	15.7	10.5	11.4	13.4	13.8	12.0	13.1	15.9	15.8	11.9	13.8	16.9	17.0
Fort Morgan	13.4	14.1	15.5	15.7	12.0	13.0	14.3	14.5	12.7	14.2	16.1	15.9	12.4	14.2	17.6	17.5
Colorado ave.[4]	13.4	13.9	16.0	16.0	12.6	13.5	15.0	15.1	12.8	14.5	16.5	16.5	12.7	14.7	17.6	17.6
Nebraska																
Scottsbluff	....	....	....	....	12.2	12.9	14.1	14.4	12.1	14.3	16.7	16.6	12.0	14.6	17.3	17.5
Gering	....	....	....	....	11.7	12.3	13.7	13.8	11.6	13.7	15.9	15.8	10.2	13.1	15.9	16.1
Bayard	13.3	14.1	16.1	16.0	12.1	13.2	15.1	15.0	11.5	14.1	16.4	16.5	10.9	13.3	16.8	16.9
Minatare	....	....	....	....	12.3	13.1	14.8	14.8	11.9	14.1	16.5	16.4	11.4	14.2	16.7	16.9
Mitchell	13.3	14.5	16.2	16.3	11.3	13.0	14.1	14.1	11.4	14.6	16.2	16.2	10.5	12.8	16.7	16.5
Lyman	14.4	15.4	17.5	17.3	11.3	12.9	14.0	14.1	12.0	14.6	16.4	16.5	11.7	14.1	17.0	17.0
Nebraska ave.[4]	13.6	14.6	16.5	16.4	11.9	12.9	14.3	14.4	11.7	14.2	16.3	16.3	11.1	13.7	16.7	16.8
Montana																
Billings	....	....	....	....	14.2	14.7	....[1]	....	13.7	16.2	....[1]	....	13.1	15.0	....[1]	....
Wyoming																
Lovell	14.7	15.8	....[1]	17.3[2]	14.3	15.0	....[1]	....	....[3]	....[3]	....[1]	....	....[3]	....[3]	....[1]	....
Colorado-Nebraska ave.[4]	13.4	14.0	16.0	16.0	12.4	13.3	14.8	14.9	12.5	14.4	16.5	16.5	12.2	14.4	17.3	17.3
G. W. S. Co. ave.[4]	13.5	14.1	....	....	12.7	13.6	....	....	12.7	13.9	....	....	12.2	14.4	....	....

[1]Individual tests not made
[2]Cossette average
[3]Sugar analyses not made
[4]Averages weighted according to number of farms sampled in each factory district.

Table 6.—Four years' summary for percentage of stand, yield in tons beets per acre, and percentage of sugar as obtained from pre-harvest samples and factory deliveries.

Area	Year	Fact. No.	Stand				Roots				Sugar			
			Farms Sampled			Factory ave.	Farms Sampled			Factory ave.	Farms Sampled			Factory ave.
			1st	2nd	Harv.		1st	2nd	Harv.		1st	2nd	Harv.	
			Percent				Tons per Acre				Percent			
Colo.-Nebr. ave.	1941	15	89.4	87.8	77.3	77.9	14.28	16.27	15.00	15.01	13.4	14.0	16.0	16.0
	1942	18	81.9	81.6	65.9	67.0	11.36	13.60	11.83	12.08	12.4	13.3	14.8	14.9
	1943	18	84.1	82.6	67.1	68.6	12.37	13.98	12.43	12.71	12.5	14.4	16.5	16.5
	1944	18	70.6	69.8	57.1	68.3	10.80	12.92	11.76	12.01	12.2	14.4	17.3	17.3
G.W.S. Co. ave.	1941	17	91.5	88.3	77.0	77.5	14.34	16.28	14.88	14.89	....*	....*	....*	....*
	1942	20	83.9	83.5	66.9	68.2	11.45	13.71	11.90	12.19	....*	....*	....*	....*
	1943	20	84.7	83.4	66.9	68.6	12.20	13.83	12.22	12.47	....*	....*	....*	....*
	1944	20	71.8	71.1	57.8	68.9	10.78	13.04	11.72	11.94	....*	....*	....*	....*

* Grower's tare samples not analyzed for sugar content in Montana and Wyoming, and pre-harvest samples not tested for sugar content in Wyoming in 1943 and 1944.

In yield of beets (table 4) there was an increase for all factories between the two dates of sampling which, for a "company average", amounted to 1.94, 2.26, 1.63, and 2.26 tons per acre, respectively, for the 4 years 1941 to 1944. With this large increase for the 2-weeks period between samplings it is obvious that the growth curve was still on the increase to place the final potential yield at an even higher figure than that shown by the second sampling date. The final harvested yield for the contracts sampled, however, showed a consistent and material drop from the second sampling date of 10.58 percent as an average for all factories for the 4 years. Considering the growth which took place after the second sampling, it is quite probable that this loss in potential harvested tonnage would have amounted to as much as 15 percent.

Some of this loss in weight of roots delivered as compared with known potential tonnage in the field may be attributed to the same sources as mentioned for stand. Another source of material loss in harvested tonnage results from desiccation, a condition which did not exist in connection with the pre-harvest samples since they were placed immediately into water-proofed bags. This is not very important from the practical standpoint, however, since any such loss in weight represents merely a loss in water and is therefore compensated by a corresponding increase in percentage of sugar. One more source of loss in yield is quite important, viz., topping too deep into the root at harvest. The importance of this can be appreciated from the fact that a cross-section slice of the root ¼ inch thick taken immediately below the lowest leaf scar amounts to about 10 percent of the total root weight. The pre-harvest samples were topped carefully and properly. Careless topping at harvest often results in considerable marketable root material being left in the fields, this source of error having entered into the harvest yields. Accurate machine harvesting may result in real savings to the grower in this respect.

For both percentage of stand and yield, the "factory average" for all contracts appears to run very slightly but rather consistently above the comparable "harvested" figures for all contracts sampled for 1942, '43, and '44. This is in contrast with the results obtained in 1941 when the harvested results for the farms sampled were nearly identical with the factory averages (table 6). In an attempt to find some explanation for this difference, a study of yields as related to size of contract was made. This study indicates that contracts of over 40 acres average slightly higher in yield than those of from 5 to 40 acres. In four factory districts contracts of over 40 acres were found to represent about 33 percent of the total acreage. These larger acreages were more likely to have been chosen in 1941, when they were classified into yield strata, where each class was represented by the same num-

ber of samples before the lottery, than in the years 1942-1944 when each contract had an equal chance to be chosen regardless of size or previous production record. This source of bias in the geographic method used in 1942 and 1943, or in 1944, could probably have been entirely eliminated by allotting the larger contracts additional chances in the lottery.

It does not appear to be possible for the contracts of 5 acres or less to influence the bias materially since the analysis of the above mentioned four-factory contracts indicates only 1.3 percent of the acreage to be in this class.

For percentage of sugar (table 5) the tare-sample averages for the farms sampled duplicated the factory average in 3 years out of 4 for a mean of all factories in Colorado and Nebraska and differed by 0.1 percent for the fourth year.

Summary and Conclusions

1. This study of random sampling of sugar beet acreage to provide a basis for harvest predictions covered a period of 4 years throughout the area served by the Great Western Sugar Company. Contracts were chosen on the basis of one per 100 acres in 1941 and one per 90 acres in 1942 to 1944. Two samples per contract were taken in 1941 and one per contract in later years.

2. The contracts chosen for sampling proved to be almost perfect samples of the entire acreage for percentage of sugar. For both stand and yield, however, the contracts chosen for 1942, '43, and '44 were very slightly but consistently lower than the general acreage. The larger contracts average slightly higher in yield than the entire acreage, which would account for the bias with respect to yield.

3. The studies reveal considerable loss in both number and weight of beets between the field and the factory. The source and importance of these losses is discussed.

4. The method of sampling as developed and used in connection with these studies appears to provide a rather accurate picture of the status of the sugar beet crop at the time of the two pre-harvest samplings. The prediction of final production must remain always a matter of personal judgment, conditioned, however, by accurate pre-harvest estimates and an intimate knowledge of growing conditions throughout the area served by the Company.

5. Three pre-harvest samples spaced 2 weeks apart, with the last sample being taken as near the beginning of the commercial harvest as possible, would provide an improved picture of the growth curve for the year and, without doubt, an improved estimate of final performance.

6. It is also suggested that the larger contracts be represented by more chances in the lottery, possibly on a basis as follows:

5— 20 acres	1 chance
21— 50 acres	2 chances
51—100 acres	3 chances
Over—100 acres	4 chances

7. A geographical stratification into sampling areas based on known fertility or productive levels might constitute some improvement over the fieldman district or dump district methods. This could be done by careful and intelligent mapping of the factory district. Such sampling areas should be large enough to include not less than eight samples taken on the sampling basis used for this study.

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Comparison of Yields From Two-Beet Hills Originating From One and Two Seeds

C. W. Doxtator and A. R. Downie[1]

There is considerable evidence in sugar beet literature to indicate that maximum beet yields are obtainable when beets are spaced as single plants in the beet fields. However, recent investigations on multiple-plant hills have shown that with appropriate acre populations, two-beet hills may yield as high as single-plant hills. Therefore it may not be necessary to produce segmented seed with as high a proportion of single-germ segments as has been done, provided two-beet hills arising from two-germ seed balls produce yields equal to those two-beet hills arising from two seed balls. A field test of two-beet hills originating from one seed and two seeds, was made at Rocky Ford, Colo., in 1945.

Experimental Procedure

American No. 1, 1942 crop seed was used in this experiment. A small amount of multiple-germ seed sized 7/64 to 10/64 inch and high in germination was obtained from the top spout of the gravity table. The seed was planted by hand on the Station farm in an eight-row strip 300 feet long. Spacing between the rows was 20 inches and between hills 15 inches. On each hill center three seeds were planted, spacing between seeds being 1½ inches in the row.

Following planting, the field was irrigated to germinate the seed. A light rain fell 10 days later and some crusting occurred, making necessary a second irrigation.

At thinning time hills in four rows were thinned to two plants which came from one seed (strip A), and on the remaining four rows two plants originating from two seeds were left (strip B). In the case that plants had not emerged in the hill to allow this origin in one or the other four-row strip, the hill was thinned to a single plant.

At harvest each beet in each of the eight rows was dug, topped, cleaned, and weighed. Weights for each beet were recorded to hundredths of pounds.

Experimental Results

Prior to thinning, stand counts were made to determine field emergence. These results have been tabulated, along with laboratory germination results, in table 1.

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Table 1.—Comparison of laboratory and field germination, 1945.

Test location	No. seeds in test	Percentage germination	Sprout count per 100 seed balls			
			Singles	Doubles	Triples	Total
Germinator	200	98.5	26.0	68.5	4.0	175.0
Field	5,712	58.2	32.6	22.0	3.6	87.4

These results indicate that even with excellent quality seed and average field conditions in this area, percent of potential was 59.1 for seed units and 49.9 for total sprouts. It is further observed that if this planting had been made with a precision drill spacing seed 1½ inches apart in the beet row, 100-inch counts of pre-thinned stands would have shown 38.8 beet-containing inches, of which number 21.7 would have been singles, 14.7 doubles, and 2.4 triples.

The stand that was obtained was not as satisfactory for this study as had been expected, and it was found necessary to thin many of the hills to singles in order to isolate such hills from the two-beet hills thinned according to the requirements of the test. At harvest it was found that in all eight rows there were only 432 two-beet hills surrounded by two-beet hills on four sides. Of these, 202 were from Strip A (two plants from one seed) and 230 from Strip B (two plants from two seeds). Since every one of the 1,904 hills harvested in the eight-row strip was numbered and the weight of each of the one or two beets in each hill obtained, it was possible to calculate the yield of all beets harvested by strip, thereby obtaining some evidence of uniformity of of the test area. It was found that Strip A produced 14.89 tons and Strip B, 14.88 tons beets per acre. It was also possible to find in both strips a total of 132 single-beet hills in competition with single-beet hills, and yields of these were calculated on an acre basis. The yields obtained from the two-beet and one-beet hills are given in table 2. Sucrose percentage for two-beet hills was obtained from four 20-beet samples taken from each strip.

Table 2.—Yield data from competitive two-beet hills.

Field strip	Origin of plants	Total 2-beet or 1-beet competitive hills	Percentage marketable beets (a)	Tons beets per acre	Sucrose percent
A	1 seed	202	86.39	16.443	17.66
B	2 seeds	230	89.13	16.359	17.43
Sign. diff. (odds 19:1)				.64 (b)	
One-beet hills		132	98.51	14.831	

(a) All beets below .25 pounds were considered non-marketable.
(b) From 7 paired comparisons.

The data obtained indicate no significant difference between the yields of the two strips, although Strip A is slightly higher in yield rank. Because of the lower acre population, one-beet hills were much lower in yield per acre.

The root associations in the two-beet hills from the A and B strips were also studied. It was expected that much intertwining would take place, especially in the two-beet hills originating from a single seed. Accordingly, four classes of root association were arbitrarily set up as follows: 1, independent; 2, slight intertwining; 3, medium intertwining; 4, severe intertwining. The results are given in tables 3a and 3b.

Table 3a.—Root associations in two-beet hills.

Strip	Plant origin	Two-beet association classes 1	2	3	4	Total pairs	Beets checked
A	2 beets from 1 seed	201	1	—	—	202	404
B	2 beets from 2 seeds	208	15	5	2	230	460

Table 3b.—Non-marketable beets in two-beet hills.

Strip	Plant origin	Two-beet association classes 1	2	3	4	Total beets checked	Percentage marketable
A	2 beets from 1 seed	54	1	—	—	404	86.39
B	2 beets from 2 seeds	46	1	2	1	400	89.13

The amount of intertwining (classes 2, 3, 4) was very low. In Strip A there were intertwining roots in less than .5 percent of the hills checked, and in Strip B, 9.6 percent, or an average of 5.1 percent for both strips. In all two-beet hills in classes 2, 3, and 4 in both strips, there were only five beets which were non-marketable. The percentage of all non-marketable beets found in the intertwining classes was 11.4 as compared to 12.5 in the independent class.

Conclusions

The data obtained in this test at Rocky Ford, Colo., in 1945 show that even the highest germinating seed is greatly reduced in germination under field conditions in this area. Under these conditions seed known to be over 70 percent in multiple sprouts produced more single sprouts than multiples in the field.

Two-beet hills from multiple-sprout seed did not differ in yield from those two-beet hills which originated from two seeds. Intertwining of roots was low in hills from both seed origins. Regardless of plant origin, 5.1 percent of the hills showed some intertwining. The percentage of non-marketable beets from this intertwining was no different than where the beets in the hill were independent in association.

The results obtained in this test suggest that, if thinning is made on a two-beet hill basis, leaving appropriate acre populations, multiple-germ seed will produce yields equal to single-germ seed.

Beet Population Studies

C. W. Doxtator and A. W. Skuderna[1]

Acre-beet populations in relation to sugar yield have been studied extensively during the past 20 years by state and federal experiment stations and sugar beet companies. During the period 1920 to 1928 in the Arkansas Valley of Colorado, experimental data showed that for average lands beets grown in rows 20 inches apart and spaced 12 inches apart in the row (26,136 beets per acre) gave most satisfactory results. Immer (*3*)[2] in experiments with acre populations ranging from 12,960 beets to 24,502 beets, in row spacings of 22 inches to 16 inches, reported yields from higher acre populations. Nuckols (*5*) obtained higher yields from acre populations of 35,500 beets than from lesser populations. Skuderna et al (*6*), in eight multiple tests conducted in six states, found significant differences in favor of 20-inch by 12-inch spacing over 20-inch by 16-inch spacings (26,136 and 19,602 beets per acre respectively) in half of the tests, the others showing no significant differences. Brewbaker and Deming (*1*) found that uniformity of stand as well as space allotment affected beet yields. These authors also had evidence of large differences in favor of 18-inch rows over 24-inch rows when equal acre populations were compared. Culbertson (*2*) in tests of acre poulations ranging from 14,256 beets to 49,004 beets, in row widths of 22 inches to 16 inches, found, as an average of seven tests, that rows spaced 16 inches and beets spaced 8 inches in the row produced higher yields than other spacing patterns and lesser acre populations. Skuderna and Doxtator (*7, 8*) found that a 20 inch by 10 inch plant spacing gave higher yields than a 20 inch by 15 inch plant spacing as an average, but a significant effect of varieties and of fertilizers was also observed.

The purpose of this paper is to present results obtained during the 3-year period, 1943 to 1945, on the relation of space allotments of sugar beets under varying conditions, to yield.

Experimental Results

Three experiments were conducted at Rocky Ford, Colo., in 1943 to test the relative yielding ability of beets in different acre populations. Beets were planted in 20-inch rows, and hills were spaced 8, 12, 16, and 20 inches in the row. Four replications of plots four rows wide by 50 feet long were used in each test,and total harvest was made of the two center rows of each plot. The tests were in cooperation with three farmers and were on land of average fertility for the

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[2]Italic numbers in parentheses refer to literature cited.

area. Data obtained from each test were averaged and are given in table 1.

Table 1.—Average results obtained from four spacing allotments in three tests, Rocky Ford, Colo., 1943.

Space allotment inches	Population per acre	Tons beets per acre	Sucrose percent	Gross pounds sugar per acre
20 x 8	39,204	17.07	15.01	5,120
20 x 12	26,136	16.59	14.85	4,934
20 x 16	19,602	16.14	14.84	4,770
20 x 20	15,682	15.83	14.91	4,721
Significant difference (19:1)		1.08	.42	316

In this experiment there were sizeable average yield differences between three test areas. There was, however, no differential response of the various spacings to the different areas. As an average of the three tests, significant differences were obtained for acre yields of beets and sugar in favor of closer spacings.

At East Grand Forks, Minn., in 1944, a test was conducted using two varieties, four fertilizer treatments, and three space allotments. This test was planted in 18-inch rows and plots were six rows wide by 50 feet long, each treatment being replicated 6 times. Two 20-beet samples were used for yield data and two 10-beet samples were taken for sugar percentage from each plot. The analysis of variance table for sugar per acre yields is given in table 2.

Table 2.—Analysis of variance table for sugar per acre yields, East Grand Forks, Minn., 1944.

Variation due to:	D/F	Sums squares	Mean squares	F
Blocks	5	591,039	118,208	
Varieties	1	1,890,854	1,890,854	7.86
Fertilizers	3	1,216,657	405,552	1.68
Spacings	2	16,859,497	8,429,749	34.88**
Varieties x fertilizers	3	2,141,764	680,588	2.82*
Varieties x spacings	2	2,070,256	1,035,128	4.28*
Fertilizers x spacings	6	354,690	59,115	
var. x fert. x spac.	6	6,117,277	1,019,546	4.22**
Remainder (error)	115	27,789,982	241,652	
Total	143	57,032,016	412,811	

* Significant beyond 5-percent point
** Significant beyond 1-percent point

From this analysis it is apparent that different space allotments greatly affected yields and were of appreciably greater importance than other variables. However, the significant effect of varieties and of fertilizers observed in this test is important enough to be taken into consideration in determining which spacing of beets will give the maximum yield.

As an average of all fertilizers it was found that one variety produced a significantly lower yield of sugar per acre than the other variety at the 18-inch by 18-inch spacing. At the 18-inch by 15-inch spacing, yields of both varieties were equal. Since the standard procedure in growing beets in the East Grand Forks area is to cross block before thinning and follow by two or more cross cultivations in a space pattern of 18 by 18 inches, using a variety which will produce the highest yields at this spacing is required.

The average data obtained on the three spacings are given in table 3. Under the conditions of this test, 18-inch by 12-inch space allotments gave significantly higher acre yield of beets and sugar than 18-inch by 15-inch spacings and higher sucrose percentage than 18-inch by 18-inch spacings.

Table 3.—Yield results from 18 by 18, 18 by 15, and 18 by 12 inch spacings of beets, East Grand Forks, Minn., 1944.

Space allotment	Population per acre	Tons beets per acre	Percentage sucrose	Pounds sugar per acre
18 x 18	19,360	17.02	14.45	4908
18 x 15	23,232	17.67	15.06	5317
18 x 12	29,040	19.06	15.10	5746
Significant difference (19:1)		.64	.26	201

In 1945 a strip test of two-beet and one-beet hills in the standard hill spacing of 18 by 18 inches, was conducted at East Grand Forks, Minn. This test was to determine if higher acre populations obtained by thinning to two-beet hills without change in the 18 by 18 inch hill pattern would increase yield. Twenty competitive hills were harvested in six adjacent locations of each strip for yield and sucrose percentage, before complete harvest of each strip. The results obtained are given in table 4.

Table 4.—Yield comparison of one-beet and two-beet Hills spaced 18 by 18 inches apart, East Grand Forks, Minn., 1945.

Hill population	Acre population	Tons beets per acre	Percentage sucrose	Pounds sugar per acre
		Data from competitive beet samples		
1	19,360	12.34	13.35	3305
2	38,720	13.36	13.88	3705
Approximate odds (4)		112:1	12:1	819:1
		Data from complete strip harvest		
1		9.07		
2		10.20		

The use of two-beet hills gave a reliable increase in yield over single beets in the 18 by 18-inch hill spacings in this test and is

further evidence that in 1945 sugar per acre yields could have been increased by use of higher acre populations in this area.

The relation of different hill populations, and spacings of hills, to yield, was compared in standard 20-inch rows at Rocky Ford, Colo., in 1945. This test was of Latin Square design planted in six replications of plots four rows wide by 50 feet long. Harvest of the two center rows for yield was made from each plot, and sucrose percentage for each plot was obtained from two 10-beet samples. Whole seed sized 7/64 to 10/64-inch and germinating 65 percent with a very high single germ count was used for the test, planting being made with a precision drill.

A relatively poor stand was obtained and it was difficult to leave beets closely spaced in those plots which were to be thinned as double and triple hills. As a result, beets in these hills were, on an average, much more widely spaced than normal for experiments of this type. The data obtained are given in table 5.

Table 5.—Hill spacing and population test in 20-inch rows, Rocky Ford, Colo., 1945.

No. beets per hill	Spacing of hills in row, inches	Population per acre after thinning	Percentage of marketable beets	Tons beets per acre	Percentage sucrose	Pounds sugar per acre
1 beet	8	39,204	85.4	9.59	15.75	3,013
1 beet	12	26,136	89.0	9.85	15.23	3,005
2 beets	18	34,848	82.3	9.13	15.49	2,843
1 beet	18	17,424	96.9	9.63	14.58	2,811
2 beets	12	52,272	69.7	8.68	15.61	2,739
3 beets	18	52,272	65.1	8.39	15.32	2,612
Significant difference (odds 19:1)				.99	.66	368

This test field was known to be low in fertility, which undoubtedly was an important factor in producing a low average yield. Under these conditions, three beet hills spaced 20 by 18 inches produced a yield of sugar per acre significantly lower than the 20 by 8 inch spacing of single beets. The single beet spacing at 20 by 18 inches produced yields not significantly different from other spacings and hill populations but was significantly lower in sucrose percentage. The percentage of marketable beets per acre was unusually low for all spacings except the single beet spacing of 20 by 18 inches. From the data obtained it is apparent that high acre populations, whether in single or multiple hills, did not greatly affect yields.

A test was made at Rocky Ford, Colo., in 1945 on a field of high fertility, of beets in 20-inch and 30-inch rows. This test was in strips 12 rows wide extending the length of the field. The beets in the 20-inch rows were thinned 12 inches apart, and those in the 30-inch rows were thinned 8 inches apart, thereby obtaining equal populations per

acre for each strip. Samplings of 100 feet of row were made in adjacent areas in each strip at harvest for yield determinations. Two 10-beet samples were obtained for sucrose percentage from each 100 feet of row harvested. The results are given in table 6.

Table 6.—Yield data obtained from 20-inch and 30-inch row spacings, Rocky Ford, Colo., 1945.

Row spacing inches	Hill spacing inches	Tons beets per acre	Sucrose percent	Pounds sugar per acre
20	12	28.14	15.57	8744
30	8	25.60	15.23	7819
Approximate odds (4)		28:1	7:1	45:1

These results are in accord with earlier investigations in this area, which led to recommendation for row spacings of approximately 20 inches. Under the conditions of this test, it would appear that beets in a space pattern of 20 inches by 12 inches were better able to absorb plant food than those in the 30-inch by 8-inch pattern.

Discussion of Results

The experiments conducted at Rocky Ford, Colo., in 1943 on three areas of different fertility showed that yield of beets could be increased by use of 20-inch by 8-inch space allotments as compared to 20-inch by 20-inch space allotments. At East Grand Forks in 1944, 18-inch by 12-inch plant spacings gave very significantly higher acre yields of beets and sugar, and of sucrose percentage, than 18-inch by 18-inch spacing. These results are in accord with previous findings of other investigators.

An analysis of the data obtained at East Grand Forks in 1944 where three commercial fertilizers and no fertilizer check were used on plots planted to two varieties and thinned to three different spacings (table 2) indicated that in this area the major factor of importance was acre population. However, highly significant F values were obtained for variety effect and for the spacing-variety-fertilizer interaction. Since spacings and varieties, and fertilizers and varieties, also gave significant F values, it is apparent in this test that both varieties and fertilizers were important in the production of sugar per acre from the various spacings. At Rocky Ford, Colo., in 1945 the data obtained on the hill spacing and hill population test did not show great differences in acre yield due to population. These results were obtained on a field of low fertility where counts indicated that only beets in wide space relationships produced a high percentage of marketable beets. This would indicate further that fertility of soil may be an important factor in determining the correct acre beet population to use.

In a preliminary test at East Grand Forks it was found that higher acre populations obtained by use of two-beet hills produced a significant increase in yield. If two-beet hills continue to produce higher yields than single beets in future tests, this method of obtaining higher yields may be used, since no change in standard farming practice would have to be made.

In a test of beets planted in 20-inch rows and thinned to 12 inches in the row, as compared with beets planted in 30-inch rows and thinned to 8 inches in the row, a significant difference in sugar per acre yield in favor of the 20-inch by 12-inch space pattern was obtained.

Conclusions

Evidence has been obtained from tests conducted in two widely separated areas that yields of sugar per acre can be increased by thinning to higher acre populations of beets. This was accomplished in one test by leaving two-beet hills, and in another test by spacing single beets more closely in the row, without change of row width. Varieties as well as fertility of soil are important in the determination of the most productive acre population. In one test where a space allotment of 240 square inches was given, beets arranged in a 30-inch by 8-inch pattern gave lower yields than those in a 20-inch by 12-inch pattern.

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A Six-Row Experimental Plot Planter

H. L. Bush and H. E. Brewbaker[1]

There are two general schemes which have been rather generally employed in planting experimental plots. One scheme is to use a can-type commercial planter, the other is to mark the field out ahead of time and plant with a hand-type garden planter, it being necessary in either case to clean out the planter hoppers at the end of each plot. For either of these methods there is always some danger of seed mixture and considerable time is involved in cleaning hoppers. The hand planter has been more generally used in the past at this Station because of its flexibility and because it was not necessary to take such large quantities of seed to the field as when a commercial-type planter is used.

The scheme used previous to 1940 by this Station was to take a bag containing an ample supply of seed to the field, the drill being calibrated for each plot immediately before planting. During the years 1940, '41, and '42 this calibrating was done in the laboratory previous to planting and various means were devised to speed up the field operation. For all the above methods the lot of seed had to be gathered up after each plot and redistributed for each successive replication.

In 1943 a scheme was adopted whereby the required amount of seed for each plot was packed in separate envelopes and all the seed in each envelope was distributed by hand through funnels attached to the drills while one man pushed the drill and another walked alongside distributing the seed. An even distribution of the seed was accomplished with a little practice. This method had the advantage of eliminating the redistribution of seed lots after each replicate, there was no remnant seed to return to the seed inventories, and any possibility of mixture of seed lots in the field was eliminated. The planting operation was speeded up materially by this method. Perhaps the most undesirable feature of this method was a somewhat uneven planting by individual drills, both as to depth of planting and row width.

In order to increase efficiency further and to obtain more uniformity of planting in 1944, six hand planters were attached to a sled framework in a similar manner to that employed in some vegetable- and beet-growing areas. The funnels were attached to the drills as in the previous year with six operators riding on a platform, the entire unit being pulled by a tractor. The operators were more efficient in distributing the seed than in 1943 since their entire attention

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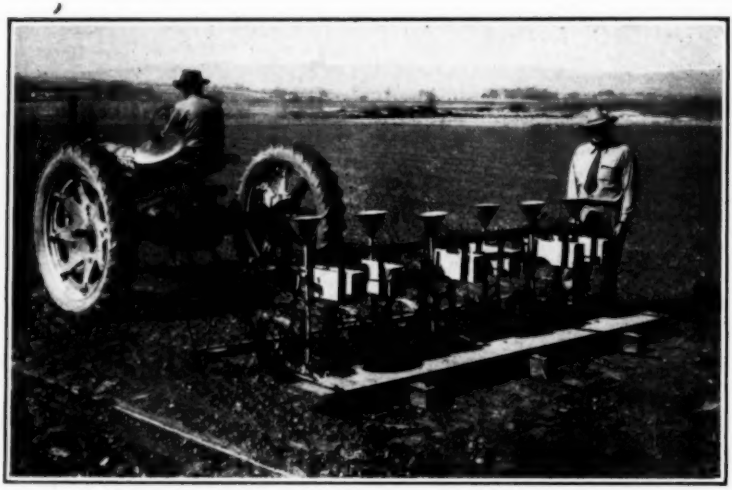


could be devoted to metering the seed through the funnels. The envelopes containing the seed for each operator were arranged in boxes in their proper order according to plots for one complete round of the drill, it being necessary to stop momentarily between each plot while the operator picked up the next envelope and emptied the seed into his hand. This method proved very successful. Disk-type commercial drill units were installed in place of the garden drills in 1945 to improve the planter further. Flexible metal tubes from the funnels to the shoes are to be replaced by smooth plastic or metal tubes in 1946.

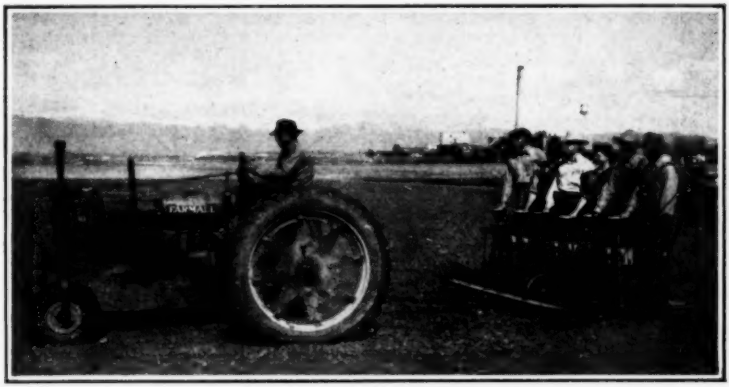
Various views of this planter are shown in figures 1 and 2.

The extent to which the efficiency of the planting operation has been improved is shown in the following table where the results are based on plots 1 row by 28 feet.

Year	Plots planted per man-hour	Acres per man-hour
1939	8.6	.009
1940	14.1	.015
1941	17.1	.018
1942	18.2	.019
1943	28.4	.030
1944	44.7	.048
1945	68.8	.074

The apparent gain in efficiency for 1945 over 1944 is due mainly to a higher degree of familiarity with the six-row scheme.

The principal qualification for the drill operators is that they must be conscientious. It is easy to obtain a high degree of uniformity



in distributing the seed where the workers are careful. Plot boundaries must, of course, be established before the planting starts. The plots as planted have been 28 feet in length, but with seed of good quality it would be feasible to hold enough seed in the hand to plant rows two or three times this length. This planter can be used for planting plots of any desired number of rows, it being simply necessary to make up an envelope of seed for each row.

The drill is transported from field to field on a low trailer, and this trailer makes a desirable work bench for arranging the seed in boxes by someone who has the field plan before him, keeping boxes filled for one round in advance of the planter.

The advantages of the six-row experimental plot planter and the present method of planting over types of equipment and methods used previously are:

1. Most of the details of preparing seed for planting may be done during the slack winter months, thereby facilitating a very rapid planting operation.
2. Some possibilities of mixtures and errors which were characteristic of earlier practices are eliminated.
3. Uniformity of depth of planting and width of rows are much improved.
4. Six rows can be cultivated at one time, thus affecting a saving of 50 percent over the four-row cultivator for this operation.

Yields From Sugar Beets With Doubles 20 Inches Apart Versus Singles 10 Inches Apart[1]

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Few experienced sugar beet growers would question the advisability of having all beets thinned to singles and evenly distributed in the row, but with mechanized thinning methods or with long-handle hoe work the ideal distribution is difficult to obtain. Frequent questions are asked about the harm sustained by leaving doubles, provided extra space is allowed when the doubles occur.

To obtain information along this line, F. G. Larmer[3] set up experiments at Davis, Calif., in 1937 and in 1938 with double beets spaced 20 inches apart compared with single beets spaced 10 inches apart. No significant differences in yield were obtained from the the two different methods of spacing. Larmer's work, published as an abstract (*1*)[4], is the only experimental work on the subject known to the writers. It was deemed advisable to repeat the experiment under Utah conditions. It also seemed advisable to compare results with different varieties.

Materials and Methods

In connection with variety tests near Salt Lake City, Utah, in 1945, a buffer strip of 16 rows was made available for the spacing experiment. Plans for the experiment were made in consultation with Bion Tolman, formerly Associate Agronomist of this Division.

The soil used for the experiment has been classified as Taylorsville loam[5] and was in a high state of fertility because of good soil management and relatively frequent applications of chicken litter. Ample irrigation water was applied during the growing season.

The beet rows were planted 20 inches apart and a uniform, relatively thick pre-thinning stand was obtained. Eight of the 16 rows were planted to variety SL 34 and the other eight rows were planted to variety SL 214. The variety SL 34 was known to be a high-sugar type and variety SL 214 was more of a yield type. In each variety eight comparisons were made between two methods of spacing. The

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[4]Italic numbers in parentheses refer to literature cited.

[5]Information on soil type was furnished by Dr. W. G. Harper from an unpublished soil survey made by the Division of Soil Survey, Bureau of Plant Industry and Agricultural Engineering, Agricultural Research Administration, U. S. Department of Agriculture.

first method consisted in thinning all the beets in a plot to singles spaced 10 inches apart. The second method consisted in thinning to doubles 20 inches apart. Plots with these two types of spacing were alternated up the field. The alternate positions of the plots made possible the use of "Student's" pairing method (*2*) for statistical analysis. The beets were planted April 6 and harvested October 12, 1945. Harvest counts showed averages of 111 beets per 100 feet of row for plants with single beets spaced 10 inches apart and 117 beets per 100 feet of row for doubles spaced 20 inches apart.

Experimental Results

The yield data are shown in table 1. For both varieties a small difference in both yield and sugar percentage was obtained in favor of the plots with beets spaced to singles 10 inches apart, but the only difference which was large enough to be statistically significant was the 1.39 tons per acre in favor of single beets spaced 10 inches apart with the variety SL 34.

Table 1.—Yield data comparing single beets spaced 10 inches apart versus doubles spaced 20 inches apart in standard 20-inch rows, with eight replicated plots on each spacing method for each of two varieties.

	Tons beets per acre		Percent sucrose	
	Variety SL 34	Variety SL 214	Variety SL 34	Variety SL214
Single beets spaced 10 inches apart	31.50	31.90	17.90	16.85
Double beets spaced 20 inches apart	30.11	30.88	17.58	16.73
Mean difference	1.39	1.02	0.32	0.11
Standard error of mean difference	0.27	0.77	0.21	0.15
Diff. ÷ S. E.	5.08**	1.33	1.55	0.76

*A figure of 2.36 represents the 5 percent point of significance.

**A figure of 3.50 represents the 1 percent point of significance.

In the plots with doubles thinned 20 inches apart there was more variation in size of individual beets, but practically all were large enough to be marketable.

Discussion and Conclusions

The data indicate a small and possibly significant increase in yield with single beets spaced 10 inches apart as compared with double beets spaced 20 inches apart. However, it should be pointed

out that the conditions of this test are extreme. Obviously, if the differences are small with practically 100 percent doubles, they would be smaller if the doubles were less than 100 percent, as they ordinarily would be in field practice. In many cases, also, a tolerance of doubles would mean less disturbance and injury to the seedlings in the thinning operations.

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A Wide- and Narrow-Row Test with Sugar Beets in Southern Idaho

ALBERT M. MURPHY and EUBANKS CARSNER[1]

A test of wide and narrow rows for sugar beets was conducted in the season of 1945 near Jerome, Idaho. The test was in connection with an incidental to curly top resistance breeding work carried on in the same field. The highly resistant variety SL 411 was used.

Methods

Planting was made April 18. Two row widths were used. One of these was the 22-inch width generally used with beets in this area. The other was 44 inches. This extreme width is only 4 inches greater than that which has been extensively tried in other areas. This width was used here because merely doubling the standard row width simplified the experimental procedure and facilitated use of regular field equipment. There were eight rows per plot in the 22-inch width and four rows per plot of the 44-inch width. The plots were 60 feet long but were reduced to 55 feet in length at harvest. The intention was to have twice as many plants per 100 feet of row in the 44-inch plots as in the 22-inch rows and thereby have the population per acre the same in both treatments. The after-thinning stand obtained was thicker in the 44-inch rows, but, as shown in table 1, it fell short of being double the number in the 22-inch rows. There were 10 replications of each treatment. Harvest yield data were based on four rows of the plots with 22-inch rows and the two center rows of the plots with 44-inch rows. Four 10-beet samples were taken from each plot at harvest for sugar and purity determinations.

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Results

The data obtained were analyzed by "Student's"[2] paired method and the results are recorded in table 1. The yield of beets averaged 3.55 tons per acre greater from the 22-inch rows, a statistically significant difference. The indicated available sugar was also significantly greater from the 22-inch rows. The average percentage of sucrose and the percent purity were both greater in the 22-inch rows, but under the conditions of the test the differences were not statistically significant.

Table 1.—Results with sugar beet rows 22 and 44 inches wide.

Row width	Indicated available sugar	Beets	Sucrose	Purity	Beets per 100 feet at harvest
Inches	Tons	Tons	Percent	Percent	Number
22	2.930	19.44	17.36	86.37	101
44	2.277	15.89	16.90	84.72	138
Difference in favor of 22-inch rows	0.653	3.55	0.46	1.65	-37
S. E. of Mean Diff.	0.10	0.58	0.24	1.03	
Difference ÷ S. E.	6.25**	6.17**	1.89	1.60	

*Exceeds 5-percent point (t = 2.26)

**Exceeds 1-percent point (t = 3.25)

Discussions and Conclusions

Row widths wider than 22 inches may be desirable from the standpoint of some mechanical harvesters, but results presented in this paper indicate that a serious loss was incurred by the use of 44-inch rows. Long-time practices in sugar beet production must be based on net financial returns. For efficiency in production, spacing of the beets to permit optimum spread of the leaves for the best light exposure needs to be considered as well as proper spacing for the optimum relationship of the plants to the soil conditions.

[2] "Student's" Collected Papers. Cambridge University Press, 1942.

Wide Row Plantings of Sugar Beets In California, 1945

R. J. TINGLEY[1]

The original trials of the "wide row plan" of sugar beet production were a part of the Holly Sugar Corporation 1944 crop mechanization studies covering total plantings of about 35 commercial acres in three different California districts. The field results with these plantings were satisfactory, and hand labor cost was so significantly lower that considerable further attention was given to the thought that perhaps almost complete elimination of hand labor in the growing and harvesting of beets might be accomplished by the adoption of the principles of our wide row plan.

It was even then apparent that a substantial reduction in hand labor costs was going to be necessary if beets were to compete with other field and vegetable crops for a normal share of the California irrigated crop acreage. There has always been a distinct peak in the hand labor requirements during the spring thinning and hoeing season, and a still greater fall peak during the beet harvesting season. The problems of securing the needed number of field laborers and justifying the high cost of such work in sugar beets has been almost impossible for the average California grower during the past war years.

It was on our realization of these facts that we decided to recommend strongly the wide row plan for mechanized sugar beet production to Holly Sugar Corporation growers in California for the 1945 season. As you might expect there was considerable opposition to the whole idea on first thought. We realized that it would be difficult to convince a practical farmer that the favorable aspects of this system would justify him to risk the possibility of a loss of the expected profit from his beet crop. This is particularly hard to put across to a farmer when he recalls all his past efforts to secure perfect stands and good thinning; also his past efforts to prevent any possible loss of even a few feet of row under his normal planting and cultural methods.

However, one of our California farmers with long and successful beet growing experience did foresee the possibilities of such savings and planted his entire crop of 330 acres on alternate 20- and 40-inch row widths (average 30-inch rows). This had the same effect as cutting out every third row at the first cultivation. His 1945 crop was plagued with several of the usual serious problems such as late planting and the replanting of nearly every acre because of wind damage.

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In spite of all these troubles he produced an average of 22.2 tons per acre on his entire acreage at a marked reduction in costs throughout, during the 1945 season when most growers were producing crops at generally increased costs!

State-wide, we succeeded in getting almost 8,000 acres of beets planted last season in California on various wide row spacings. These plantings covered nearly every possible combination of soil type, irrigation system, seasonal condition, and farming equipment throughout California from Santa Ana in the south to Hamilton City in the north. None of these farmers had to buy any specialized equipment to adopt this system to their own farm. Certainly it is only reasonable to expect that most of the results obtained in 1945, with this radical departure from customary procedure, were not quite as good as can be expected with further experience and anticipated improvement in equipment and details of cultural practices. Considerng these facts, with the generally good results actually obtained, we believe there will be additional incentive for our growers to recognize further the convenience and savings of the wide row plan. We currently estimate that more than 75 percent of our 1946 California acreage will be in wide rows.

Following are some of the row widths used on a field basis last year: 24 inches, 26 inches, 28 inches, 30 inches, 32 inches, 34 inches, 36 inches, 38 inches, and 40 inches uniform spacing as well as alternate 20-inch and 40-inch combinations. Considerable of this acreage was planted on single-row beds and some with ordinary flat planting. Numerous types of planters were used, such as sled planters for ridged fields, with Planet Jr. or Cobbley seeder units; John Deere, International, Oliver Superior, and Moline wheel planters were used on flat plantings. The cultivating was done with any and all the standard makes and types of cultivators.

Mechanical weed control and irrigating were both performed more effectively and more economically because of this system of planting. Thinning and hoeing costs were reduced from 10 percent to as much as 40 percent as compared to conventional methods.

Practically all the harvesting on this wide-row acreage (except for 20-inch by 40-inch combination) was done with Marbeet single-row harvesters, all without the use of any hand labor for opening up fields. Considerable latitude in the kinds and sizes of tractors used was possible because of the unusual width between rows.

Satisfactory and efficient performance of the Marbeet single-row harvesters was made possible because of such factors as better traction, less interference from tops and weeds, and less soil to be handled than is inherent with 2-row harvesters. Also, it is going to be easier to adapt some satisfactory beet top recovering system with wide row

plantings than would ever be possible with standard 20-inch row spacings.

We had in 1945 one large experimental planting on the Holly Sugar Corporation Tracy Ranch which fully confirmed our belief that no significant difference in sugar-per-acre should develop when beets are planted according to our wide row plan.

Table 1.—Results obtained on the Tracy Ranch, Randomized block design, four treatments, 18 replicates.

Plot	Treatment	Yield Tons per acre	% Sucrose	Gross sugar per acre Pounds
A	32-inch rows machine thinned	18.022	12.46	4,504
B	32-inch rows hand thinned	19.401	12.18	4,735
C (Check)	20-inch rows hand thinned	20.011	11.78	4,716
D	20-inch rows machine thinned	19.326	11.03	4,284
General mean		19.190	11.86	4,560
F value		6.904	3.2299	1.5313
5% point		2.79	2.79	2.76
1% point		4.20		
S E of mean		.3185	4.13	4.13
Diff. req. for sig.		.904	.98	486

Recent comparisons of actual costs in Imperial Valley 1945 fall plantings show the following savings on 34-inch row spacing:

	Per acre
Average cost thinning and hoeing on conventional double-row bed plantings averaging 21 inches	$25.00
Average cost thinning and hoeing on wide row single beds (34 inches)	18.00

It is estimated that an additional $15 per acre saving will be made in harvest costs on the single-row beds with a Marbeet one-row harvester as compared with conventional double-row beds which must of necessity be hand harvested.

The results of our extensive commercial field experiences, together with our own past experimental results, have led us to decide that there should be no significant difference in the sugar-per-acre production of beets planted in row widths of 26 inches, 28 inches, 30 inches, 32 inches, and 34 inches when properly cared for, as compared with conventional row spacings, so long as both systems are handled to contain approximately the same populations of beets per acre.

From a practical farming standpoint it is apparent to us that any row width from 26 inches to 34 inches can be expected to accomplish the desired savings and the mechanical benefits without materially affecting the sugar per acre yields. The actual wide-row spacing selected should be determined by available farm equipment, irrigation practices, and the mechanical harvesting program to be used.

The acceptance of the principles of the wide row plan, with its obvious savings in man hours for thinning and hoeing, and also its greater adaptability to complete mechanization of harvest, may well be the factors which influence the average beet grower to plant increased acreages of sugar beets on his farm in 1946 and in the future.

Effects of Variation in Spacing on Sugar Beet Yields in California

H. J. Venning, W. B. Marcum, G. D. Manuel[1]

To determine the effects of variation in row spacings on yield of sugar beets while maintaining approximately the same population per acre, the following trials were run during the 1945 season at Woodland, Gilroy, and King City. Twenty-inch flat planting and 14-inch by 20-inch ridge planting were used as the checks in comparison with 30-inch and 40-inch ridge planting. Each treatment was replicated three times.

Spacing of beets down the row was very uniform, thinning having been done by hand with the aid of marked sticks so that the spacing would be as uniform as possible.

There were no visual differences in growth throughout the season. It was noted, however, that the furrows between the 30-inch and 40-inch plantings had more growth of water grass. This was probably due to less shading from the tops in the two treatments.

Treatment	Gross tons of sugar per acre	Tons of beets per acre	Percent of sucrose	No. of beets harvested p/unit acre	No. of beets per 100 feet of row
		(Sacramento Valley)			
14-inch by 26-inch ridge	3.957	25.211	15.7	111	111
20-inch flat	3.867	25.722	15.0	108	108
30-inch ridge	3.585	23.515	15.2	95	127
40-inch ridge	3.066	21.105	14.5	90	180
F value*	10.757	10.210	4.102	25.305	
2 x Sa†	0.346	1.842	0.674	5.532	
		(Santa Clara Valley)			
16-inch by 26-inch ridge	4.250	25.353	17.5	104	104
40-inch ridge	3.574	20.788	17.2	93	186
F value**	25.367	19.328	0.932	14.877	
2 x Sa†	0.120	2.300	0.682	8.066	
		(Salinas Valley)			
14-inch by 26-inch ridge	5.588	34.108	16.4	93	93
40-inch ridge	5.056	30.530	16.6	85	170
F value***	3.443	16.114	0.062	7.957	
2 x Sa†	0.810	2.520	1.698	7.644	

*F value of 4.76 required to give odds of 19:1 against deviations noted being due to chance.

**F value of 6.61 required to give odds of 19:1 against deviations noted being due to chance.

***F value of 10.13 required to give odds of 19:1 against deviations noted being due to chance.

†Two times the standard error of a difference. This value is generally accepted as the minimum for the statistical significance.

Data were analyzed as a randomized complete block.

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The Effect of Single and Double Plants on Sugar Beet Yields

S. W. McBirney[1]

One of the questions of major importance in connection with mechanized thinning of sugar beets is the effect on yields of single and double plants left by the thinning operation. A set of plots was put in this past spring at Fort Collins in cooperation with the Colorado A & M College to determine in part the answer to this question. Several others are also working on different phases of the same question and when all the information is brought together we hope to have an answer.

In mechanized thinning operations double plants frequently occur and they are usually counted in one of two ways in determining after-thinning stands. Sometimes the double is counted as two beets to give the total number of beets per hundred feet of row. Sometimes the double is counted as a hill along with the singles as separate hills to give the total number of hills per hundred feet. There has been a difference of opinion with mechanical thinning as to whether the number of beets or number of hills should be kept at the desired thinned stand, for example of 100 per hundred feet of row.

This matter of total number of beets versus total number of hills was taken into consideration when the set of plots was laid out. On part of the plots the total number of thinned beets was kept at 100 per hundred feet of row and the percentage of the beets which were singles and doubles was varied in 20-percent steps from 100 percent singles to zero percent singles and 100 percent doubles. This meant that the number of hills for these plots was 100 hills for 100 percent singles, 90 hills for 80 percent singles, 80 hills for 60 percent singles and down to 50 hills for 100 percent doubles. On the remainder of the plots the number of thinned hills was kept constant at 100 per hundred feet and the percentage singles as before was varied by 20-percent steps from 100 percent singles to zero singles and 100 percent of the hills as doubles. On this group of plots the number of beets was 100 beets for 100 percent singles, 120 beets for 80 percent singles and 20 percent doubles, and up to 200 beets for zero singles and 100 percent doubles.

The plots were carefully hand thinned by 10-foot sections of row so that each section had its desired number of single and double plants. The planting was with 7 to 10/64″ segmented seed at 4 to 6

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pounds per acre, but germination was good and there were enough doubles to obtain the desired stands. Some of the double plants were right together when they were thinned, having evidently come from a double-germ segment or two segments dropped together. Other double plants were separated by an inch or two and evidently came from two segments. No attempt was made to try to get doubles of one type or the other, but there were perhaps about as many of one as the other. Plots were four rows wide and about 35 feet long so that 30 feet of the two center rows could be harvested and avoid border effect. Each treatment was replicated five times in randomized blocks.

These plots together with the rest of the field were carried through to harvest, being irrigated three times and being cultivated and hoed and otherwise treated all alike. They were harvested in early October.

The plots were harvested by hand, keeping the two 30-foot rows in each plot separate. The beets were washed to eliminate discrepancies of dirt tare. The data taken included number and weight of marketable beets, a marketable beet being taken as one of 1¼ inch or greater diameter, and the total number of beets including unmarketable roots so as to get a check on losses of numbers of beets from thinning to harvest time.

Table 1 shows the data taken on this set of plots. In general all the beets left at thinning time were accounted for at harvest either

Table 1.

Treatment No.	Thinned stand			Harvest stand		Yield	
	Percentage doubles	Beets per 100 feet	Hills per 100 feet	Total beets per 100 feet	Marketable beets per 100 feet	Tons per acre	Percent of check
1	0	100	100	100.0	97.6	12.25	100
2	20	100	90	100.0	94.6	12.31	101
3	40	100	80	98.6	95.5	12.31	101
4	60	100	70	105.0	97.6	11.66	95
5	80	100	60	95.6	92.4	12.52	102
6	100	100	50	101.7	94.6	11.07	90
7	20	120	100	119.0	111.0	11.75	96
8	40	140	100	139.0	122.3	10.27	84
9	60	160	100	147.5	126.3	9.82	80
10	80	180	100	163.2	131.6	9.21	75
11	100	200	100	174.5	137.5	9.82	80
	Difference for significance					±1.17	

as marketable or unmarketable roots up to the point where the thinned stand was 140 beets per hundred feet of row. With heavier thinned stands part of the beets did not grow through until harvest to make roots large enough to find. When the number of thinned

beets per hundred feet was kept at 100, even though the percentage of doubles increased to 100, nearly all the beets came through to harvest as marketable beets. However, when the number of thinned hills was kept at 100 per hundred feet and the number of beets in the thinned stand increased as the percent of doubles increased, the number of marketable beets increased steadily but the number which did not make marketable beets also increased.

The yield data are shown in the last two columns of the table, one being expressed in tons per acre and the other in percent of the check treatment which was 100 beets per hundred feet of row, all beets being singles. The differences in yield between treatments in tons per acre required for significance at the 95-percent level is shown. This data shows that when the number of thinned beets is kept at 100 per hundred feet, the yield is not decreased by increased percentages of doubles until the percentage of doubles exceeds 50 or 60 percent. Beyond this point there is a downward trend of yield which barely reaches significance with 100 percent doubles. However, when the number of beets left at thinning increased as the percentage of doubles increased, the yield decreased even though the number of hills was kept constant at 100 per hundred feet. This decrease was significant with 40 percent or more doubles.

The trends of yields with increased percentages of doubles is shown even better by the curves in Figure 1 than by the tabulated data. The curves are estimated from the plotted data. The upper

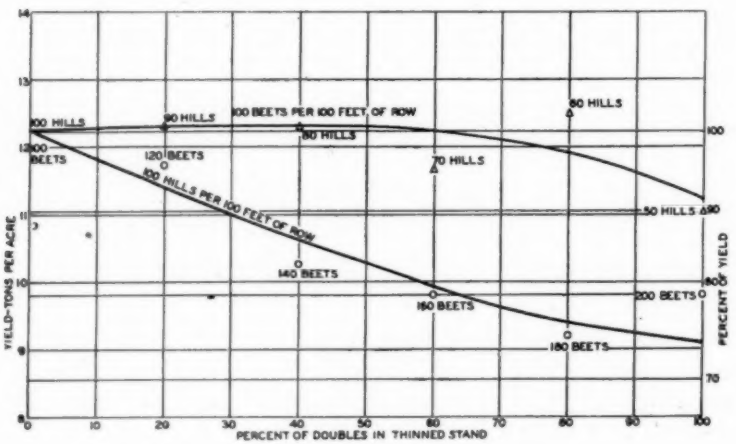

Figure 1.—Curves showing the effect on harvest yield of varying percentages of single and double beets.

curve indicates that when the thinned stand is kept at 100 beets per hundred feet there is only a small decrease in yield even with a comparatively high percentage of doubles. On the other hand the lower curve indicates that with increased doubles and a corresponding increase in number of thinned beets per hundred feet there is a significant decrease in yield which reaches a 25-percent decrease at about 80 percent doubles.

It should be pointed out that this set of plots was grown on a field having a 12- to 13-ton-per-acre level of soil fertility. The data probably would have been different on soil of a higher or lower fertility level. The stand of 100 beets per hundred feet of row was taken as a check because that seems to be the commonly accepted desired thinned stand in this area.

Population and Distribution Studies With Sugar Beets

BION TOLMAN[1]

Established sugar beet culture in the intermountain area centers around the planting of beets in 20- and 22-inch rows with a subsequent spacing of plants 11 to 12 inches apart in the row to give a population of approximately 25,000 beets per acre. Recent mechanization of sugar beet agriculture has raised the question as to whether the traditional pattern of distribution may not be changed without adversely affecting yields. The present paper is a report of some studies conducted to determine optimum populations in relation to different distribution patterns and also to determine the effect on yield of varied distribution patterns.

Experimental Procedure

The two major tests reported here include 20-inch, 26-inch, 32-inch, and 38-inch row widths with 8-inch, 10-inch, 12-inch, and 15-inch spacings in the row. These two tests were split-plot experiments with four replicated plots of each of the 16 treatments. The results of these tests are supplemented by results from other spacing studies and population and distribution studies involving a comparison of hand and mechanical thinning.

Experimental Results

Results of the row width test at Granger, Utah, are shown in table 1. It is evident from these results that, under the conditions of this experiment, distribution pattern had more effect on yield and sucrose

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Table 1.—Row width and spacing tests, 1945, Granger, Utah. Hill Brothers Farm.

Spacing in Row	Row widths as indicated				Average for spacing in the row
	20"	26"	32"	38"	
8 inch spacing					
Beets per acre	36,540	29,136	24,500	20,253	27,622
Tons per acre	28.48	26.14	25.56	25.35	26.38
Sucrose percentage	17.24	16.78	16.24	16.16	16.60
Gross sugar per acre	4.910	4.374	4.149	4.096	4.382
10 inch spacing					
Beets per acre	30,697	24,774	20,807	16,639	23,229
Tons per acre	28.26	26.89	26.48	25.24	26.72
Sucrose percentage	17.15	16.75	16.28	15.93	16.53
Gross sugar per acre	4.844	4.500	4.315	4.015	4.418
12 inch spacing					
Beets per acre	25,784	20,938	16,090	13,862	19,168
Tons per acre	30.07	28.40	26.98	25.76	27.80
Sucrose percentage	16.98	16.41	15.98	15.78	16.29
Gross sugar per acre	5.106	4.665	4.312	4.060	4.536
15 inch spacing					
Beets per acre	21,010	16,636	12,312	10,626	15,146
Tons per acre	29.50	28.48	25.76	26.25	27.50
Sucrose percentage	16.60	16.20	15.61	15.18	15.90
Gross sugar per acre	4.901	4.614	4.019	3.975	4.377
Average for row widths					
Tons per acre	29.08	27.48	26.20	25.65	
Sucrose percentage	16.99	16.54	16.03	15.76	
Gross sugar per acre	4.940	4.538	4.199	4.036	

Replicated test with four replications of each treatment.

content than did per acre population. The effect of population is apparent within any one of the row widths. In almost every case the highest yield of beets per acre occurred where the beets were spaced 12 inches apart in the row. The data indicate that spacing beets closer than 12 inches in the row was not beneficial regardless of the increase in row width. In all cases a spacial allotment per beet which approached a square was more efficient than a spacial allotment which was extremely rectangular. This is evidenced by the fact that the yield decreased progressively as the space allotment became increasingly rectangular in shape. For example: When the per acre beet population was held constant at 20,000 to 21,000 beets per acre the yield was 29.50 tons per acre with 15-inch spacing on 20-inch rows; 28.40 tons per acre with 12-inch spacing on 26-inch rows; 26.48 tons per acre with 10-inch spacing on 32-inch rows and 25.35 tons per acre with 8-inch spacing on 38-inch rows. There was also a progressive drop in sucrose percentage over this same spacial pattern regardless of the fact that each beet had the same total space allotment. The same result was repeated when the per acre population of beets was held constant at approximately 25,000 to 26,000 beets per acre. With 12-inch

spacing on 20-inch rows the yield was 30.07 tons per acre; with 10-inch spacing on 26-inch rows the yield was 26.89 tons per acre; and with 8-inch spacing on 32-inch rows the yield dropped to 25.56 tons per acre. Sucrose percentage decreased in a similar manner.

Distorting space allotment had more effect on yield than either increasing or decreasing space allotment within the limits tried. However, increasing or decreasing space allotment had more effect on sucrose percentage than did distortion or pattern of the space allotment. Increasing space allotment, either by increasing row width or by increasing spacing in the row, depressed sucrose percentage. However, the decrease becomes progressively greater as the population per acre decreases or as the space allotment per beet increases. For example: With 8-inch spacing the sucrose percentage decreased 1.08 percent as the row width was increased from 20 inches to 38 inches; with 10-inch spacing the decrease was 1.22 percent; with 12-inch spacing the decrease was 1.20 percent and with 15-inch spacing the decrease was 1.42 percent.

We have seen that distribution pattern had a marked effect on the yield of beets per acre and that population or space allotment as well as distribution pattern had a marked effect on sucrose percentage. Sugar per acre was affected mainly by row width or distribution pattern. It should be noted, however, that in every instance there was a drop in sugar per acre as spacing within the row increased from 12 to 15 inches. Under the conditions of this experiment maximum yields of sugar per acre were produced with 12-inch spacing within the row. With 12-inch spacing within the row, the yield of sugar per acre was 5.106 tons on 20-inch rows and only 4.060 tons on 38-inch rows. This makes a decrease of 2,080 pounds of sugar per acre caused by the combined effect of row width and decreased population per acre. However, if population per acre is held constant at approximately 25,000 beets per acre the yield of sugar per acre ranges from 5.106 tons per acre with 12-inch spacing and 20-inch rows to only 4.149 tons per acre with 8-inch spacing on 32-inch rows. This decrease of 1,914 pounds in the yield of sugar per acre is all due to distribution pattern, inasmuch as population or total spacial allotment was held constant. The same relationship held when population was kept constant at 21,000 to 20,000 beets per acre. The yield of gross sugar per acre was 4.901 tons with 15-inch spacing on 20-inch rows and it decerased to 4.096 tons per acre with 8-inch spacing on 38-inch rows.

The test on Sagar's farm at American Fork, Utah, was somewhat of a contrast to that on the Hill Brothers Farm at Granger, Utah. The results of this test are given in table 2. It is evident from the data that on the average 12-inch spacing was optimum regardless of row width. In this test, however, the effect of spacial distribution was

Table 2.—Row width and spacing test, 1945, American Fork, Sagar's Farm.[1]

Spacing in row	Row widths as indicated				Average for spacing in the row
	20"	26"[2]	32"	38"	
8 inch spacing					
Beets per acre	37,374	30,173	23,849	19,571	27,742
Tons beets per acre	20.82	20.27	21.54	18.80	20.36
Sucrose percentage	12.57	12.15	12.69	12.39	12.45
Gross sugar per acre	2.612	2.460	2.672	2.004	2.437
10 inch spacing					
Beets per acre	29,534	23,909	19,152	14,031	21,656
Tons beets per acre	21.66	21.43	22.36	18.81	21.06
Sucrose percentage	12.66	12.52	12.15	12.05	12.34
Gross sugar per acre	2.742	2.684	2.715	2.256	2.599
12 inch spacing					
Beets per acre	23,000	19,502	15,028	12,243	17,443
Tons beets per acre	22.16	20.97	21.46	20.64	21.31
Sucrose percentage	12.37	12.31	11.25	12.35	12.07
Gross sugar per acre	2.930	2.573	2.415	2.548	2.616
15 inch spacing					
Beets per acre	19,898	14,878	12,088	9,904	14,192
Tons beets per acre	22.17	19.28	22.58	19.08	20.78
Sucrose percentage	12.67	12.72	12.35	12.35	12.52
Gross sugar per acre	2.798	2.444	2.810	2.355	2.602
Average for row widths					
Tons beets per acre	21.70	20.19	21.98	19.33	
Sucrose percentage	12.57	12.42	12.11	12.28	
Gross sugar per acre	2.770	2.540	2.653	2.291	

Replicated test with four replications of each treatment.

[1]Tests conducted in cooperation with Dr. Bertram Harrison of the Brigham Young University, Provo, Utah.

[2]Some morning glory spots on one set of the 26-inch row no doubt account for the slight decrease in yield as compared to 32-inch rows.

much less than in the one at Granger, Utah. This is no doubt accounted for by the extreme fertility level on the American Fork plot. The contrast in fertility level between these two plots is shown by a comparison of the sucrose percentage figures. The average sucrose percentage at the Granger plot was 15.76 and at the American Fork plot it was 12.28 or a difference of 3.48 percent. The difference in fertility was further borne out by the extreme top growth at the American Fork plot. Further evidence that this plot was located on abnormal fertility is reflected in the results of grower test strip plantings which were located in the same county. The results of these tests are given in table 3. The similarity between these results and the Granger, Utah, test is evident.

The inter-relation of per acre population and distribution was also shown on a series of plots where hand and mechanical thinning were compared. The results of these tests are given in table 4. It is evident that 100 beets per 100 feet of row was optimum spacing on the hand thinning plots. The yields were 23.52, 24.08, and 22.47 tons per

Table 3.—Row width tests, Utah County, 1945. Tons beets per acre from 20-inch rows as compared with 30-inch rows.

Grower's name	Tons beets per acre		Loss in tonnage per acre
	20" rows Regular	Every 3d row out 20-40 wide and narrow combination	
Jennings Meanson	24.39	22.21	2.18
Bert Hanson	21.23	17.72	3.51
Kenneth S. Christensen	23.10	21.13	1.97
W. J. Money	20.65	17.16	3.49
Selvoy J. Boyer	19.29	13.64	5.65
Elden Evans	16.66	13.02	3.64
Average	21.73	18.37	3.36

Grower strip tests—16 rows wide comparing 16 rows of regular 20 inch rows with 16 rows with every third row cut out giving a 40 inch-20 inch wide and narrow combinations or an average row width of 30 inches.

acre for 75, 100, and 125 beets per 100 feet of row respectively. On mechanically thinned plots it was advantageous to increase the number of beets per 100 feet of row. The yields were 21.04, 21.87, and 22.45 tons per acre for 75, 100, and 125 beets per 100 feet of row respectively.

With hand thinning all blocks were reduced to singles and these single plants were uniformly distributed over the entire 100 feet of row. Under these conditions of uniform distribution, wide spacing did not greatly affect yields. With mechanical thinning about 20 percent of the blocks contained doubles. Consequently, with 75 beets per 100 feet of row there were only 62 blocks of beets; with 100 beets per 100 feet of row there were 80 blocks of beets, and with 125 beets per

Table 4.—Comparison of the yield and population distribution from hand and mechanically thinned plots.

Beets per 100 feet of row	Hand thinned		Dixie thinned		Difference in hand and mech. thinning
	Beet-containing blocks per 100 feet of row	Tons beets per acre	Beet-containing blocks per 100 feet of row	Tons beets per acre	
	Number	Tons	Number	Tons	Tons
Granger, Utah					
75 beets per 100 feet	75	23.52	62	21.04	—2.48
100 beets per 100 feet	99	24.08	81	21.87	—2.21
125 beets per 100 feet	123	22.47	102	22.45	—0.02
Average	98.6	23.36	81.7	21.78	—1.58
Belle Fourche, South Dakota					
75 beets per 100 feet	75	10.76	60	8.88	—1.88
100 beets per 100 feet	100	10.93	78	9.23	—1.70
125 beets per 100 feet	124	10.50	107	9.70	—0.80
Average	100	10.73	81.7	9.27	—1.46

Table 5.—Distribution and population studies with hand and mechanical thinning in Idaho.[1]

Thinning method	Beets left per 100 feet of row	Blocks of beets per 100 feet of row	Yield in percent of check	Percent singles
	Number	Number	Percent	Percent
Merrill farm				
Hand thinning (check)	83	81	100.0	94.0
50% machine thinning	83	79	95.6	90.0
71% machine thinning	86	75	91.7	75.0
100% machine thinning	91	75	83.1	66.5
DeKay farm				
Hand thinning (check)	90	88	100.0	95.0
100% mechanical (Dixie)	100	81	93.2	70.6
100% mechanical (cross cultivated)	82	58	82.3	66.0

[1]Studies by A. J. Bigler.

100 feet of row there were 102 blocks of beets. Increasing the blocks of beets from 62 to 102 per 100 feet of row gave a more favorable distribution and the improved distribution pattern resulted in increased yields.

These results were also borne out by similar studies in South Dakota. The yield on hand thinned plots was 10.76 tons, 10.93 tons, and 10.50 tons for 75, 100, and 125 beets per 100 feet of row respectively. On mechanically thinned plots the yield was 8.88 tons, 9.23 tons, and 9.70 tons for 75, 100, and 125 beets per 100 feet of row respectively. Mechanical thinning tests in Idaho[2] also pointed out the importance of distribution of stand as well as total number of beets per 100 feet of row. In all cases the yield was in proportion to the number of beet-containing blocks left per 100 feet of row. The results of these tests are given in table 5. At the Merrill farm yields decreased as the percentage of machine work increased and distribution became more irregular as the percentage of machine increased. At the DeKay farm, regularity of distribution was in proportion to the number of blocks left per 100 feet of row and yields followed this same relationship.

Discussion

The results reported indicate that distribution pattern affected yields to a greater extent than did the range of population per acre which was included in the tests. This is in accord with the findings of Brewbaker and Deming (*1*)[3] who state that uniformity of stand is relatively more important than the particular spacing used. The

[2]Mechanical tests in Idaho were conducted by .A J. Bigler.

[3]Italic numbers in parentheses refer to literature cited.

decrease in yield from 20- to 26-inch rows also follows the pattern indicated by the work of Brewbaker and Deming (*1*). They report a decrease of over 2 tons per acre when row widths were increased from 20 to 24 inches even though poulations were greatly increased in the row to compensate for the wider row.

The limits within which beets can effectively utilize space has been rather definitely defined. Most all spacing studies show a decrease in yield as spacing within the row is increased beyond 12 inches. Under conditions of high fertility, such as that on the Toppenish, Wash., plot, yield may be maintained with row spacings out to 15 inches, but even under high fertility, yields begin to decline as spacing within the row is increased to 20 inches. In consideration of this fact there is no reason to assume that beets can advantageously use a space allotment between rows in excess of 20 inches. In fact spacing data suggest that an increase in number of rows per acre might be advantageous from the standpoint of maximum production.

Mechanical thinning studies indicate that it is more important to consider final distribution pattern than it is total beets per 100 feet of row. In view of this fact the stand on mechanically thinned plots should be calculated in terms of blocks per 100 feet of row rather than in terms of beets per 100 feet of row. Much of the success of mechanical thinning also depends on the ability of beets adjacent to skips to compensate for the skip through increased growth. Brewbaker's and Deming's (*1*) work shows that as the size of the gap or skip increases, the percentage of compensation from adjacent beets decreases. Decreased row widths rather than increased row widths would be advantageous in mechanical thinning from the standpoint of making it possible for beets in one row to compensate for skips in an adjacent row. It also becomes evident that a beet can utilize a square space more efficiently than it can an equivalent area which is rectangular in shape. This would suggest that yields might be increased by increasing the number of rows per acre rather than by increasing the number of beets per 100 feet of row.

Increasing space allotment per beet decreased sucrose percentage regardless of whether the increased space allotment resulted from increased spacing in the row or increased width between the rows. There was also a decrease in sucrose percentage as row widths were increased, even though spacing within the row was decreased so that there was no increase in space allotment per beet.

The effect of space allotment on sucrose content indicates that in general spacing within the row should not be wider than 12 inches, inasmuch as wider spacing does not increase yield even under conditions of high fertility.

Summary

The results of tests showing the effect of plant population and the distribution pattern of given populations on yield, sucrose content, and gross sugar per acre are reported. Variations in plant population and distribution pattern were obtained by varying row width and also by varying spacing within the row.

There was no significant difference in tonnage yield between beets spaced 8 inches, 10 inches, 12 inches, or 15 inches in the row on any of the row widths studied. There was a progressive decrease in yield as the row width increased from 20 inches to 26 inches, 32 inches, and 38 inches.

The tests indicated that a square distribution pattern of beet population on an acre was much more efficient than where the space allotment for each beet is extremely rectangular in shape.

The inter-relation of population and distribution was also shown on plots where hand and mechanical thinning were compared. The stand on mechanically thinned plots should be determined on the basis of beet-containing inches rather than total beets. This provides for a better distribution pattern.

In all tests, increasing the space allotment per beet whether within the row or between the rows resulted in decreased sucrose percentage.

Literature Cited

1. Brewbaker, H. E., and Deming, G. W. Effect of Variations in Stand on Yield and Quality of Sugar Beets Grown Under Irrigation. Jour. of Agr. Res., Feb. 1, 1935.

Summary of Date-of-Planting Experiments With Sugar Beets in Nebraska and Wyoming, 1938-1945[1]

S. B. NUCKOLS[2]

Plantings of sugar beets by commercial growers in this area formerly were principally done between April 15 and April 30. During the past 5 years the practice has radically changed and a large number of growers now plant their entire beet crop before April 15. Many commercial sugar beet growers had held the opinion that there is a greater danger of having to replant the crop when plantings are made before April 15 than when the plantings are made later than that date. They believed that the greatest cause for replanting came from frost damage to the sugar beet plants. In the date-of-planting tests reported here, it has been found that frost damage was only slightly more common to beets planted early in April than to beets planted the latter part of April.

Observations made in connection with these tests indicate the chief factor bringing about poor stands of sugar beets is poor germination caused by lack of sufficient soil moisture.

In these districts, irrigation for germination of seed is not used, since water is not commonly available for irrigation until about May 10. The districts in which these tests were conducted usually have rainfall in April that supplies sufficient moisture for germination of early planted sugar beets, but the later beets are planted in April the greater is the chance that moisture for germination will be lacking. In these date-of planting tests, the entire field has been prepared for seeding before the first planting, and this favors the late plantings over the usual late commercial plantings since these are made on land that has been prepared only a few days previously. Preparation of the land for planting always dissipates part of the available soil moisture. In other tests in which the land was prepared in mid-March and in mid-April and planted April 20 it was found that the yields on the land prepared early was about 2 tons of beets per acre more than that from the land plowed later.

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[1]Tests at Torrington, Wyo., were conducted in cooperation with the Goshen County Experiment Farm of the Wyoming Agricultural Experiment Station. Acknowledgment is made to Superintendent L. H. Paules for assistance in these experiments. Tests at Mitchell, Nebr., were made at the U.S.D.A. Scotts Bluff Field Station. Acknowledgment is made to Lionel Harris, superintendent, for assistance in these experiments.

[2]Agronomist, Division of Sugar Plant Investigations, Bureau of Plant Industry, Soils, and Agricultural Engineering, Agricultural Research Administration, United States Department of Agriculture.

Tests concerned with the effects of different dates of planting of sugar beets were started at Torrington, Wyo., in 1938 at the Goshen County Experiment Farm and have been continued each year until 1945. During 5 of these years, similar tests have been conducted at the U.S.D.A. Scotts Bluff Field Station, Mitchell, Nebr. The two places are about 30 miles apart and climatic conditions are very similar. The difference in elevation between the two sites is small.

In all, 13 tests have been conducted in which sugar beets were planted at 5- or 10-day intervals from March 20 to April 30. When weather conditions did not permit of planting on the selected date, it was done as soon as possible thereafter. These tests have been conducted on two farms that differ considerably in soil type. The land at Torrington is a sandy loam and the soil at Scottsbluff is classified as Tripp fine sandy loam. Randomized-block plot design has been used in all tests, with replications ranging from 5 to 10 for each planting date. Data for the 13 tests have been analyzed by the analysis-of-variance method and are summarized in tables 1 to 4. The data as reported are from plots which have not been fill-in planted in any instance. During the period in which these experiments were conducted, the only plots replanted because of frost injury were the 1941 plantings at the Scotts Bluff Station. These replanted plots were irrigated to germinate the seed. The year of 1941 represents the

Table 1.—The average number of sugar beet plants per 100 feet of row from plantings made in the period from March 20 to April 30. Experiments were conducted at Goshen County Experiment Farm, Torrington, Wyo., and at the Scotts Bluff Field Station, Mitchell, Nebr. (Data are given as averages of 5 to 10 replications for each date of planting for the specified year.)

		Plantings were made on or as soon as possible after specified date.				
Location of field	Year	March 20	April 1	April 10	April 20	April 30
Torrington, Wyo.	1938	51	49	40	45	37
Torrington, Wyo.	1939	77	73	53	25	46
Torrington, Wyo	1940	56	48	43	30	24
Torrington, Wyo.	1941	50	73	84	85	75
Torrington, Wyo.	1942	92	97	82	82	84
Torrington, Wyo.	1943	88	92	85	65	64
Torrington, Wyo.	1944	72	78	67	74	51
Torrington, Wyo.	1945	80	81	77	55	63
Torrington, Wyo.	Mean	71	74	66	58	56
Mitchell, Nebr.	1940	42	60	44	38	26
Mitchell, Nebr.	1941	69	62	97	97	85
Mitchell, Nebr.	1942	75	80	49	56	58
Mitchell, Nebr.	1943	78	61	70	80	80
Mitchell, Nebr.	1945	83	82	80	75	66
Mitchell, Nebr.	Mean	69	69	68	69	63
Mean of both areas		70	72	67	62	58

Difference required for significance for means of both areas, odds 19 to 1—9.1 plants.

only instance of May irrigation and all plots in the field were irrigated.

In experiments of this character, the time of emergence of sugar beets is perhaps more important than the planting date. The March plantings of sugar beets normally emerge about April 15 but in one instance they emerged April 3 and did not frost. In 1945, no plants emerged until April 25. As is to be expected, there is less difference in the yields associated with differential planting dates when emergence in early planting is delayed. Furthermore, the greatest differences in yield have occurred when the late plantings suffered from lack of moisture for germination. As an average of the 13 experiments, the stands of sugar beets in the March 20 plantings are significantly better than in April 30 plantings (table 1). The April 10 plantings also have significantly better stands than the April 30 plantings. These stand differences, being in favor of the early plantings, indicate that the factor of frost damage to the sugar beets is not so great as the damage to stands that is caused by the lack of normal rainfall to insure germination of the later plantings.

There was a significant gain in acre yield of roots in favor of the March 20 and April 1 plantings in comparison to those planted on April 20 and April 30. The average yield for April 20 plantings

Table 2.—Average tons of sugar beet roots harvested per acre from plantings made in the period from March 20 to April 30. Experiments were conducted at Goshen County Experiment Farm, Torrington, Wyo., and at the Scotts Bluff Field Station, Mitchell, Nebr. (Data are given as averages of 5 to 10 replications for each date of planting for the specified year.)

Location of field	Year	Plantings made on or as soon as possible after specified date.				
		March 20	April 1	April 10	April 20	April 30
				Tons		
Torrington, Wyo.	1938	10.0	10.0	8.9	8.3	6.2
Torrington, Wyo.	1939	21.0	18.4	15.4	9.9	10.9
Torrington, Wyo.	1940	23.7	20.8	20.2	17.0	11.9
Torrington, Wyo.	1941	16.4	19.2	19.4	19.2	17.4
Torrington, Wyo.	1942	21.6	21.7	17.0	18.5	17.5
Torrington, Wyo.	1943	17.9	17.8	16.2	12.8	12.5
Torrington, Wyo.	1944	19.0	19.1	17.5	18.6	13.7
Torrington, Wyo.	1945	14.6	13.9	13.3	11.3	11.1
Torrington, Wyo.	mean	18.0	17.6	16.0	14.5	12.7
Mitchell, Nebr.	1940	19.0	20.1	20.1	17.8	13.0
Mitchell, Nebr.	1941	22.6	21.8	25.1	23.6	22.5
Mitchell, Nebr.	1942	21.1	21.2	19.4	19.9	19.2
Mitchell, Nebr.	1943	16.1	16.0	16.2	15.2	15.8
Mitchell, Nebr.	1945	15.8	15.7	16.6	16.6	13.7
Mitchell, Nebr.	mean	18.9	19.0	19.5	18.6	16.8
Mean of both areas		18.3	18.1	17.3	16.1	14.2

Difference required for significance for means of both areas, odds 19 to 1—1.47 tons.

was significantly greater than the corresponding average for the April 30 plantings. These 13 tests carried on over 8 seasons indicate, therefore, that for best yields of sugar beets in these districts planting should be completed by April 15 (table 2). There has been more difference in the yields from the different dates of planting on the Torrington field than on the Scotts Bluff Station field. The Torrington field is sandy land and the Scotts Bluff Station field is somewhat heavier land. Sandy land is especially subject to soil moisture deficiency for germination of late planted beets, and it is probable that the Scotts Bluff Station plantings benefited to some degree from the greater moisture-holding capacity of the soil.

If leaf diseases are not a factor, early planted beets usually show a higher sucrose percentage than late planted beets. In these experiments, no significant differences in sucrose percentages are shown among the averages obtained for the different planting dates (table 3).

Since the difference in sucrose percentage of roots taken from the different plantings was not significant, differences in acre-yield of gross sugar are attributable largely to the effects of root yield. The average acre-yields of sugar for the two earliest dates of planting significantly exceed the corresponding average sugar yields for the April 20 and April 30 plantings (table 4).

Table 3.—Average sucrose content of sugar beet roots harvested from plantings made in the period from March 20 to April 30. Experiments were conducted at Goshen County Experiment Farm, Torrington, Wyo., and at the Scotts Bluff Field Station, Mitchell, Nebr. (Data are given as averages of 5 to 10 replications for each date of planting for the specified year.)

Location of field	Year	Plantings made on or as soon as possible after specified date.				
		March 20	April 1	April 10	April 20	April 30
				Percent		
Torrington, Wyo.	1938	15.0	14.6	14.8	15.3	15.0
Torrington, Wyo.	1939	15.0	15.0	14.6	14.1	14.3
Torrington, Wyo.	1940	13.7	13.4	13.6	13.3	12.6
Torrington, Wyo.	1941	15.0	14.7	15.3	15.8	16.4
Torrington, Wyo.	1942	14.2	14.3	13.9	14.7	15.0
Torrington, Wyo.	1943	15.7	15.8	15.8	16.6	16.5
Torrington, Wyo.	1944	16.8	16.7	16.3	17.0	15.4
Torrington, Wyo.	1945	16.7	16.4	16.4	16.2	16.6
Torrington, Wyo.	mean	15.3	15.1	15.1	15.4	15.2
Mitchell, Nebr.	1940	12.0	13.1	13.4	13.3	13.0
Mitchell, Nebr.	1941	15.2	15.6	15.6	15.4	15.9
Mitchell, Nebr.	1942	15.0	15.1	13.7	13.8	14.3
Mitchell, Nebr.	1943	14.4	14.3	14.3	14.7	14.9
Mitchell, Nebr.	1945	17.6	17.6	17.1	17.1	17.3
Mitchell, Nebr.	mean	14.8	15.1	14.8	14.9	15.1
Mean of both areas		15.1	15.1	14.9	15.2	15.2

Difference required for significance for means of both areas, odds 19 to 1—0.36 percent.

Table 4.—Average yields per acre of gross sugar from plantings made in the period from March 20 to April 30. Experiments were conducted at Goshen County Experiment Farm, Torrington, Wyo., and at the Scotts Bluff Field Station, Mitchell, Nebr. (Data are given as averages of 5 to 10 replications for each date of planting for the specified year.)

Location of field	Year	Plantings made on or as soon as possible after specified date.				
		March 20	April 1	April 10	April 20	April 30
				Tons		
Torrington, Wyo.	1938	1.505	1.452	1.318	1.280	.922
Torrington, Wyo.	1939	3.154	2.770	2.239	1.420	1.569
Torrington, Wyo.	1940	3.234	2.789	2.738	2.180	1.454
Torrington, Wyo.	1941	2.458	2.838	2.969	3.035	2.862
Torrington, Wyo.	1942	3.069	3.115	2.362	2.721	2.630
Torrington, Wyo.	1943	2.803	2.809	2.551	2.121	2.057
Torrington, Wyo.	1944	3.210	3.210	2.857	3.233	2.116
Torrington, Wyo.	1945	2.449	2.282	2.193	1.821	1.850
Torrington, Wyo.	mean	2.723	2.657	2.402	2.226	1.931
Mitchell, Nebr.	1940	2.282	2.624	2.678	2.347	1.686
Mitchell, Nebr.	1941	3.417	3.406	3.906	3.620	3.582
Mitchell, Nebr.	1942	3.102	3.203	2.658	2.762	2.752
Mitchell, Nebr.	1943	2.297	2.290	2.299	2.223	2.340
Mitchell, Nebr.	1945	2.750	2.751	2.826	2.830	2.397
Mitchell, Nebr.	mean	2.771	2.855	2.873	2.756	2.551
Mean of both areas		2.749	2.733	2.583	2.430	2.170

Difference required for significance for means of both areas, odds 19 to 1—0.31 ton.

Conclusions

These tests indicate that no significant difference in the average yield of sugar beets was obtained from plantings made in March as compared with plantings made up to April 10. The experiments show that, as an average, there was a loss of more than 2 tons of beets per acre if planting was delayed until April 20, and a loss of about 4 tons of beets was experienced when the planting was delayed until April 30. Differences of from 2 to 4 tons of beets per acre, taking into account the consistency of their recurrence, warrant the recommendation that earlier planting be practiced in the Torrington and Scottsbluff districts. There is considerable evidence that since the cause of low yields is lack of moisture for germination where the plantings are made later than April 15 and that sandy lands are more subject to the moisture deficiency, there should be a greater effort made for early planting on sandy lands than on heavy lands. In any attempt to apply these findings in favor of early planting of sugar beets to other districts, careful consideration should be given to the particular climatic factors that operated here to bring about these differences in yield.

GENETICS, BREEDING, SEED, AND VARIETIES

A Comparison of Selected and Random Advanced Generations of Hybrid Beet Strain 520[1]

G. W. Deming[2]

Hybrid beet strain 520 was produced at Rocky Ford, Colo., in 1935. A description of this hybrid and a review of yield trials of 520 and some early advanced generations of it were presented to this Society at its Denver meeting in 1940 (*1*)[3]. Briefly, hybrid strain 520 is a white-rooted third generation of a cross of a sugar type variety sugar beet and a globe type red garden beets. For the production of hybrid 520, white beets of desirable type and good to high weight and percentage sucrose were selected from the second generation of this cross and planted as an isolated group for seed production. Approximately 110 pounds of seed was obtained from this group of a few hundred plants.

Since 1939 the generations of this hybrid have been advanced and yield trials continued at Fort Collins, Colo.[4] The advancement of the generations has followed two lines, both starting from 520 as a base: (1) Continuous selection as for the original strain 520 and (2) continuous random increases. Selected generations have been advanced to the seventh and random generations to the sixth generation, respectively. Seed of the various generations has been produced from isolated group plantings of approximately 150 to 500 roots each. For the selected line, beets were picked at harvest for type and for average to large size. After individual analyses of these roots for percentage sucrose, the group for planting was made up of roots which were average or better for both weight and percentage sucrose. For the random line all beets as they grew in the field were saved to the number of several hundred and a group planting made the following spring for seed production, without selection in any way for type, weight, or sugar content. In general, storage losses of these roots have been light and any effect of a natural selection due to such stor-

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[1]Paper No. 205, Scientific Journal Series, Colorado Agricultural Experiment Station.

[2]Associate Agronomist, Division of Sugar Plant Investigations, Bureau of Plant Industry, Soils, and Agricultural Engineering, U. S. Department of Agriculture.

[3]Italic numbers in parentheses refer to literature cited.

[4]Agronomic investigations of the Division of Sugar Plant Investigations at Fort Collins, Colo., are cooperative with the Agronomy Section of the Colorado Agricultural Experiment Station and are conducted on the Agronomy Farm of the latter agency.

age losses of roots is believed to be negligible for any of these random increases.

In the early trials hybrid strain 520 produced high yields of roots with usually somewhat lower percentage sucrose than that of comparable commercial varieties of sugar beets. However, because of the high yield of roots of the hybrid, the acre yields of gross sugar frequently equalled or exceeded those of the best comparable commercial variety. On the basis of these early trials it was believed that the hybrid might be of value, particularly in sugar beet growing areas where the tonnage types of sugar beets normally produce the largest acre yields of sugar. However, it was obvious that commercial production of third generation seed of this or similar hybrids was impractical because of the cost. For this reason the performance of advanced generations of this hybrid became of interest.

In 1944 seed production of advanced generations of hybrid 520 had proceeded to the selected seventh and the random sixth generation, thus making it possible in 1945 to compare the selected fourth to seventh and the random fourth to sixth generations with the original selected third generation in one comprehensive variety test. Also included in this test were a local commercial variety as a check and 3 other strains, making a total of 12 varieties in the test. This test was planted on the Agronomy Farm at Fort Collins, Colo. The soil is Fort Collins Loam, light textured phase, and the general level of fertility is moderately high. The preceding crop was spring wheat. The wheat stubble was fall-plowed after the application of about 10 loads per acre of barnyard manure. The test consisted of 6 randomized replications with the plots 8 rows in width and 30 feet in length; the 6 inside rows of each plot were harvested and two 20-beet samples taken for percentage sucrose determinations. Thus the yield of roots was determined from the weight, after washing, of all beets from 180 feet of row per plot. The test was planted May 10, thinned June 19 to 22, and harvested October 16 and 17. The planting date, May 10, was at least 2 weeks later than the optimum date for the region, but unfavorable weather prevented earlier planting. The yields obtained in this test were not high but are considered very good for May 10 planting.

In mid-June, just before thinning, it was observed that the beet plants on much of this part of the field had an abnormal appearance. The leaves were curled and slightly brittle and there was more or less burning of the leaf edges. Growth of many of the plants appeared to have stopped. Frost injury on June 16 was at first suspected as a cause of this condition; however, a closer examination revealed the presence of great numbers of a small, gray leaf hopper and it is be-

lieved that the feeding of these insects had had a toxic effect on the beet plants. Most areas of this test and all the varieties included were more or less affected. However, it was observed that the random fifth and sixth generations of hybrid 520 were probably more generally and severely affected than any other of the varieties in the test. Recovery was rapid after thinning and all parts of the test had resumed normal growth by late June. In general excellent stands were obtained on all plots and no conditions, other than the leaf hopper damage, were observed during the season to impair the validity of the test. The general reliability of this test is believed to be very good. A summary of the test is presented in table 1.

Varieties 9 and 10 are of interest in the present discussion only in that they indicate the possibility that other strains may be obtained from crosses of sugar beet with other beet varieties which may equal or surpass the relatively high root yields of hybrid strain 520. This test was not affected by leaf spot. The performance of variety 11 (U. S. 215 x 216) is not in line with previous tests or a companion test in 1945 in which 2-1-00 compared more favorably with the local commercial check variety.

Table 1.—General summary hybrid 520 strains trial, Fort Collins, Colo., 1945. (Data given as six-plot averages).

Variety or strain	Acre yields		Percentage sucrose
	Gross sugar (pounds)	Roots (tons)	
1. 520 Sel. 3rd	3,951	14.48	13.32
2. '37-304 Sel. 4th	3,802	14.16	13.42
3. '39-303 Sel. 5th	4,230	15.17	13.96
4. '42-309 Sel. 6th	4,244	15.47	13.76
5. '44-306 Sel. 7th	3,924	14.12	13.92
6. '38-301 Rand. 4th	3,925	15.10	13.02
7. '42-305 Rand. 5th	3,685	13.73	13.41
8. '44-305 Rand. 6th	3,644	13.56	13.47
9. '42-306 Sel. 3rd	4,054	16.23	12.52
10. '43-300 Sel. 3rd	4,042	16.68	12.14
11. 2-1-00 U.S. 215 x 216	3,273	11.33	14 41
12. Local com'cl check	3.748	14.14	13.26
General mean of test	3,877	14.55	13.38
F value	4.12**	8.39**	5.14**
2 x the S. E. of a Diff. (odds of 19:1)	pounds 378	tons 1.36	percentage 0.78
S. E. of mean in percent of general mean	percentage 3.44	percentage 3.31	percentage 2.06

Notes:

No. 9 is the selected third generation of a cross of U. S. Nos. 200 and 215 x globe type red garden beet.

No. 10 is the selected third generation of a cross of commercial sugar beet x Giant Pink Top Half Sugar stock beet.

No. 11 is a leaf spot resistant variety. This test was not affected by leaf spot.

In this test none of the advanced generations of the hybrid differed significantly from 520 in yield of gross sugar or roots and none of them had a significantly higher or lower percentage sucrose than 520. Certain of the differences between some of the advanced generations themselves exceed the amounts required at the 5 percent level for probable significance. The selected fifth and sixth generations were higher in gross sugar production than the selected fourth or the random fifth and sixth generations. In root yield the random fifth and sixth generations were significantly below the selected fifth and sixth generations. Also the selected sixth very nearly exceeds the sleected fourth and seventh generations by amounts sufficient for significance. Only one of the generations, the random fourth, had a markedly low sugar content; its percentage sucrose in this test of 13.02 was significantly lower than either that of the selected fifth or seventh generations. In comparison with the commercial sugar beet check variety, only the selected fifth and sixth generations of the hybrid produced significantly more gross sugar, and none of the hybrid strains differed significantly from this check in yield of roots or in percentage sucrose.

This test was inconclusive as to progressive improvement or deterioration of the 520 strain through either of the lines of selection. In root yield the selected fifth and sixth generations and the random fourth generation were relatively high, while the random fifth and sixth generations and, to a lesser degree, the selected fourth and seventh generations were relatively low. In the case of the selected line of advancement the low fourth is followed by the high fifth and sixth generations which in turn are followed by a low seventh generation. In the random advancement of generations there was an apparent deterioration in yield from the fourth to the fifth generation which was not followed by further decrease in the sixth generation. In connection with the above comparisons it should be noted that the leaf hopper infestation in June appeared to have had a more consistently adverse effect on the random fifth and sixth generations than on other strains in the test. Only one of the advanced generations differed significantly from any of the others in percentage sucrose. This was the random fourth generation, which was low in sugar content.

A possible explanation of the apparent variations from generation to generation lies in the fact that seed production has been from group plantings of at most a few hundred roots each. Thus, the parent material for each succeeding generation may or may not have been a true sample of the previous generation. This could be particularly true in the case of random advancement.

In the period from 1936 to 1945 there have been many tests of the original hybrid 520 and the successive generations as seed of these became available. These tests have varied from observational strip plantings to extensive replicated tests. Very few of these tests have consistently included the same strains of the hybrid, and the commercial sugar beet check variety used in each of them has varied from extreme sugar to tonnage type. However, in every instance the commercial sugar beet check variety was a variety in general use by growers in the area where the test was conducted. Any adequate statistical analysis of the combined data from all these tests appeared impractical if not impossible and has not been attempted. For these reasons no general summary of these tests will be presented. However, some general conclusions which are believed to be valid may be drawn from these older tests.

In the earlier tests a sugar type sugar beet check variety was more frequently the commercial check variety used for comparison with hybrid 520. In these tests the hybrid usually had a lower percentage sucrose than the commercial check variety and the difference was often highly significant. In the later years of testing, the commercial sugar beet check variety has more often been of a tonnage type and the various hybrid generations have often equalled or slightly exceeded the commercial check variety in percentage sucrose. However, whatever the differences, they have seldom reached the level of probable significance in these later tests.

Individually or in varying combinations the original hybrid strain 520 and each of the advanced generations, with the exception of the random sixth and selected seventh generations, have been included in two or more tests since 1936. In every case the average root yield of any one of the hybrid strains, regardless of the generation, has exceeded the average of the comparable commercial sugar beet check variety, often by a highly significant margin. The instances in which the commercial variety has exceeded some one strain of the hybrid in a single test have been rare. The random sixth and selected seventh generations of the hybrid were included in only one test (1945) and their root yields were 95.9 and 99.9 percent, respectively, of the commercial check variety in that test.

One or more strains of the hybrid and a commercial sugar beet variety as a check have been included in 21 different tests. From these 21 tests a total of 71 individual comparisons of some one strain of the hybrid with the commercial check variety are possible. Out of these 71 possible comparisons the hybrid strain has exceeded the check 27 times in yield of gross sugar per acre. In a majority of these cases the difference was probably not significant.

In the period 1939 to 1945, inclusive, there have been eight tests in 5 of these years which included a commercial sugar beet variety, the original hybrid strain 520, and one or more each of the selected and random advanced generations of the hybrid. Ignoring the differences, if any, in the successive generations in each line of advancement, the average performance of the four varieties in the eight tests was as shown in table 2.

Admitting that the earlier generations of advancement of the hybrid have contributed a greater share to the averages than were contributed by the later generations, and that random and selected generations were not represented equally in all tests, certain of the trends shown by these averages seem to be worthy of note. The advancement of generations by continuous selection appears to have maintained root yield and to have improved slightly the percentage sucrose. When the advancement in generations was at random, percentage sucrose was maintained but root yields declined about 4 percent. The loss in root yield when the advancement of generations was at random has a little more than cancelled the original advantage of the hybrid over the check in yield of gross sugar per acre but has

Table 2.—Summary of performance of hybrid strain 520, selected advanced generations of 520, random advanced generations of 520, and commercial sugar beet check variety. Averages of eight tests in 5 different years (1939-45).

Variety	Acre yields		Percentage sucrose (Percentage)	Total single values used in averages
	Gross sugar (Pounds)	Roots (Tons)		
1. Hybrid 520	4,338	14.70	14.86	8
2 Selected advanced gen. of hyb.	4,385	14.60	15.39	23
3. Random advanced gen. of hyb.	4,140	14.11	14.86	16
4. Commercial variety check	4,194	13.65	15.47	8
No. 1 in percent of No. 4	103.43	107.69	96.06	
No. 2 in percent of No. 4	104.55	106.96	97.74	
No. 3 in percent of No. 4	98.71	103.37	96.06	
No. 2 in percent of No. 1	101.86	99.32	101.75	
No. 3 in percent of No. 1	95.44	95.99	100.00	
No. 3 in percent of No. 2	94.41	96.64	98.28	

Notes:

1939: Replicated tests at Fort Collins and Rocky Ford, Colo., and at Sheridan, Wyo. Strip plantings at Fort Morgan, Colo.

1941, 1943, 1944 and 1945: Replicated tests at Fort Collins, Colo.

Hybrid 520 and a commercial check variety occurred once in each of the tests. One or more selected and one or more random advanced generations of the hybrid occurred in each of the tests.

When two or more generations of either line of advancement of the hybrid occurred in a test, all values for that line of advancement were averaged and the resultant figure used as the appropriate value for the line in that particular test, thus bringing the data for each of the four varieties to a common basis for the averages of all tests.

not entirely cancelled its advantage over the check for root yield in these tests.

The possibility that a variety hybrid such as 520 could be carried to commercial production, after some degree of selection, by random seed increases is not entirely ruled out by these tests.

Conclusions

A high-yielding third-generation hybrid beet variety can be obtained from sugar beet x garden beet and probably from other similar variety crosses by the careful selection of the most desirable second-generation roots for seed production.

Because of the amount of time and expense involved in producing a relatively small amount of third-generation hybrid seed, the commercial production of such a variety is impractical.

Advancement of a hybrid variety to the seventh generation by continuous selection has had little effect on its performance. A possible slight loss in yield of roots, in comparison with the original third generation, has been offset by a slight increase in percentage sucrose.

Advancement of the same hybrid variety to the sixth generation by continuous random increases has resulted in a small loss in yield of roots and no change in percentage sucrose.

Evidence of any progressive change in this hybrid variety by either of the lines of advancement of the generations has been inconclusive.

The possibility of obtaining a high-yielding hybrid variety similar to hybrid beet strain 520 for commercial use, particularly in regions where the tonnage types of sugar beets give highest acre production of sugar, appears to justify further production and testing of such hybrids and the investigation of methods by which seed of the hybrid variety may be made available in quantity and at a moderate cost. Direct increase of the seed of such a hybrid variety to commercial quantities without further selection in the later generations has not been definitely proved impractical by these tests.

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Bolting Performance of Sugar Beet Breeding Stocks

C. E. Cormany[1]

In the production of commercial sugar beet seed it is desirable, other things being equal, to use seed varieties of high seed reproductive ability. Large tonnages of seed per acre make for cheaper production and a more profitable crop.

It has been observed that the old stand-by types of European seed formerly used so extensively in this country vary considerably in their ability to produce seed. Since most of the American seed varieties can be traced back to these original types it is reasonable to expect that the new ones will produce seed in about like manner. This is generally true and unless careful selection has been made in the early development of the varieties for highest seed production some of the low seed producers may persist.

In attempting to maintain a high level of seed producing ability in Holly Commercial seed, many breeding strains of seed and all elite or stock seed is being tested for its seed reproductive ability under the actual conditions where the commercial seed is grown.

While no detailed data are offered, a few observations in the nature of a progress report will be made in this paper.

Beet breeding and improvement work for Holly Sugar Corporation is headquartered at Sheridan, Wyo., with substations elsewhere in the Rocky Mountain area. Practically all the initial increases of breeding lines are made at Sheridan, using the mother beet or steckling method. Increases of seed for commercial use are made by the over-wintering method in New Mexico, Arizona, California, and Oregon.

Before these over-wintering commercial increases are planted it is highly desirable that the seed production habits of each variety be known. This information is now being secured by plantings of elite material in small plots beside commercial fields in the Arizona area a year or two prior to actually using it for commercial seed plantings. By this method the best seed producers are determined and are favored over the less productive of equal agronomic value when direct increase or crosses are made. In many instances strains of high merit for their agronomic characteristics or disease resistance have been found to be poor seed producers. Such outstanding strains are not

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discarded but in subsequent plantings only the best, most promising seed producing individuals are selected. This type of selecting for desirable seed production is not new to sugar beet breeders.

In the production of commercial beet seed in America by the over-wintering method, it is desirable that at least 90 percent of the total plants in the field form seed stalks and of these seed stalks not less than 85 to 90 per cent participate in the seed crop. An even greater percentage of participating bolters is desirable. Early bolting is favored over late bolting, and excessive vegetativeness or leafiness of seed plants is not desirable. These standards are probably higher than the average actuals of commercial fields.

With this standard in mind, 99 strains of seed supplied by the Holly Sugar Corporation have been studied under actual growing conditions in the Phoenix area. Unfortunately it was not feasible to make actual seed yield records on all these plots. Only field notes descriptive of top growth characteristics were made.

The data secured indicate that only one-fourth of the strains tested could be classified as acceptable, about one-fourth were very poor, and one-half were intermediate, many of which can be greatly improved by further selection for seed production.

In these tests, strains with curly top resistant blood were as a whole much better seed producers than non-curly top resistant kinds. Very few of our curly top resistant lines are poor seed producers.

Strains being developed for leafspot resistance were distributed about equally as good, fair, and poor seed producers.

The so-called agronomic group which are not developed for resistance to either curly top or leafspot afford a great opportunity for selective improvement for seed production.

It is not always possible to predict accurately the seed yielding ability of hybrids.

The only sure way of knowing the seed producing ability of a new strain or variety is to test it out under the conditions where the commercial seed crop will be grown.

Further studies of the seed producing habits of breeding strains of sugar beets are planned.

Sugar Beet Varietal Trials in the San Joaquin, Sacramento, and Salinas Valleys of California

LeRoy Powers[1]

From 1939 to 1944, inclusive, rather extensive sugar beet varietal trials have been conducted by the Spreckels Sugar Company. These tests were located in the San Joaquin, Sacramento, and Salinas Valleys. The purpose of this article is to report the results of these trials.

The most obvious major factors limiting yield of sugar per acre are diseases and bolting; and the two most important diseases are curly top and downy mildew. In some years bolting may limit production in those fields planted early (December and January). Such being the case the tests will be separated and analyzed on the basis of those in which disease and bolting are negligible, those in which curly top is a factor but bolting and mildew are not, and finally those in which bolting and mildew are factors but curly top is not. Bolting and mildew are considered together in these tests because a definite separation is not possible. Finally, the data for the five varieties and selections will be averaged for locations and dates of planting and studied to obtain information concerning the environmental variability.

Materials and Methods

Five varieties were carried for the duration of the tests. These were U. S. 22, U. S. 33, Improved U. S. 33, U. S. 15, and Old Type (R & G).

In discussing the data, any differences mentioned will have been shown to be statistically significant (odds as great as or greater than 19 to 1).

Genetic Variability

The averages given in table 1 are for tons of available sugar per acre, tons of beets per acre, percentage sucrose, and coefficients of apparent purity when disease and bolting are not factors. The data are for the 5-year period from 1939 to 1944, not including 1942; and the averages given are for the 13 locations and dates of planting shown in table 4. The five varieties do not differ significantly in yield of available sugar per acre. U. S. 22 tends to be high in tons of beets

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Table 1.—Averages for tons of available sugar per acre, tons of beets per acre, percentage sucrose, and coefficients of apparent purity when disease and bolting are not factors—1939 to 1944, inclusive.

Variety or selection	Tons per acre		Percentage sucrose	Coefficients of apparent purity
	Available sugar	Beets		
U. S. 22	3.791	27.18	16.17	85.01
U. S. 33	3.793	26.42	16.48	85.54
U. S. 15	3.709	26.17	16.52	85.42
Old Type (R & G)	3.806	26.60	16.37	85.25
Imp. U. S. 33	3.744	26.07	16.44	85.38
Standard error of mean	0.046	0.279	0.078	0.157
Sig. Diff. (Odds 19:1)	0.130	0.789	0.221	0.444

per acre but low in percentage sucrose and coefficient of apparent purity. None of the differences between the remaining four varieties for any of the four characters are statistically significant.

The data for the same four characters when curly top is a factor but bolting and mildew are not factors are given in table 2. The varieties fall into three classes in respect to their resistance to the virus causing curly top. Comparatively speaking, as determined by tons of beets per acre, Old Type (R & G) is very susceptible, U. S. 15 possesses a slight degree of resistance, U. S. 33 possesses a fair degree of resistance, and U. S. 22 and Improved U. S. 33 are highly resistant. Percentage sucrose and coefficient of apparent purity do not seem to be influenced by the degree of curly top prevalent in this test.

Table 3 gives the tons of available sugar per acre, tons of beets per acre, percentage sucrose, and coefficients of apparent purity when bolting is a factor and mildew may be. The two tests included in the averages were conducted at Salinas, Calif., in 1939 and 1940. U. S.

Table 2.—Averages for tons of available sugar per acre, tons of beets per acre, percentage sucrose, and coefficients of apparent purity when curly top is a factor—Vernalis and King City, 1940.

Variety or selection	Tons per acre		Percentage sucrose	Coefficients of apparent purity	Percentage of plants with curly top
	Available sugar	Beets			
U. S. 22	2.797	20.98	15.86	84.6	12
Imp. U. S. 33	2.782	19.29	16.90	85.4	19
U. S. 33	2.643	18.04	17.01	85.9	38
U. S. 15	2.005	14.30	16.34	85.1	76
Old Type (R & G)	1.517	10.61	16.68	85.5	74
Standard error of mean	0.096	0.875	0.221	0.340	
Sig. Diff. (Odds 19:1)	0.272	2.474	0.625	0.962	

Table 3.—Averages for tons of available sugar per acre, tons of beets per acre, percentage sucrose, and coefficients of apparent purity when bolting is a factor and mildew may be—Salinas, Calif., 1939 and 1940.

Variety or selection	Tons per acre		Percentage sucrose	Coefficients of apparent purity	Percentage of	
	Available sugar	Beets			Plants that bolted	Plants with mildew
U. S. 15	5.176	40.17	15.49	83.16	2	23
Old Type (R & G)	4.904	40.77	15.11	81.58	10	24
U. S. 33	3.762	30.06	14.85	82.46	32	31
U. S 22	3.683	34.36	13.51	79.35	20	37
Imp. U. S. 33	3.423	29.23	14.42	81.24	33	27
Standard error of mean	0.111	0.615	0.231	0.682		
Sig. Diff. (odds 19:1)	0.314	1.739	0.653	1.929		

15 and Old Type (R & G) comprise a class having the greatest degree of resistance to bolting and they do not differ materially in respect to tons of available sugar per acre, tons of beets per acre, percentage sucrose, coefficient of apparent purity, and percentage of plants with mildew. The second most resistant class contains U. S. 22. This variety is lower than U. S. 15 and Old Type (R & G) in tons of available sugar per acre, tons of beets per acre, percentage sucrose, and coefficient of apparent purity; and it is higher in percentage of plants with mildew. U. S. 33 and Improved U. S. 33 comprise the third class. The only satistically significant difference between these two varieties is in tons of available sugar per acre and this difference is only just statistically significant. The coefficients of apparent purity are not significantly lower than those of U. S. 15 and Old Type (R & G), but tons of available sugar per acre and tons of beets per acre are materially lower.

The comparisons between U. S. 22 and U. S. 33 and Improved U. S. 33 are interesting. U. S. 22 is lower than these two varieties in percentage sucrose and coefficient of apparent purity and higher in tons of beets per acre, but not materially different in tons of available sugar per acre. From the data of this table it is evident that the effects of bolting and possibly those of mildew are two-fold, tons of available sugar per acre being lowered by a reduction in both tons of beets per acre and percentage sucrose. Furthermore, the effects are multiplicative rather than additive which gives greater weight to simultaneous changes.

Environmental Variability

The averages for tons of available sugar per acre, ton of beets per acre, percentage sucrose and coefficients of apparent purity for the different locations and dates of planting are given in table 4.

Table 4.—Averages for tons of available sugar per acre, tons of beets per acre, percentage sucrose, and coefficients of apparent purity for the different locations and dates of planting. The averages are for the five varieties and selections given in table 1.

Locations and dates of planting			Tons per acre		Percentage sucrose	Coefficients of apparent purity
			Available sugar	Beets		
Salinas	March	1939	5.000±0.073	37.13±0.250	15.98±0.158	84.20±0.392
Woodland	January	1939	4.515± .068	30.84± .428	16.83± .148	86.99± .279
Woodland	March	1941	3.100± .056	30.02± .353	12.36± .135	83.54± .228
Banta Carbona	April	1941	4.251± .095	28.83± .623	17.22± .127	85.62± .223
King City	March	1941	4.391± .037	28.67± .210	18.23± .076	84.02± .180
Woodland	April	1941	2.693± .060	26.85± .477	12.28± .119	81.68± .291
Salinas	April	1940	3.097± .044	25.96± .253	14.74± .114	80.94± .234
Davis	March	1944	3.529± .093	24.98± .558	16.40± .075	86.14± .077
Woodland	March	1939	3.399± .073	23.91± .502	16.66± .173	85.33± .269
Woodland	April	1940	3.269± .055	23.76± .443	16.01± .166	85.94± .268
King City	March	1944	3.009±	21.89± .391	18.44± .078	89.42± .....
King City	February	1941	3.459± .033	21.40± .275	18.73± .142	86.31± .228
Woodland	May	1943	3.444± .141	20.11± .744	19.24± .063	89.02± .044
Average			3.674	26.49	16.39	85.32

Since each entry is an average for the five varieties and selections, the differences noted for any one character can be attributed to environmental variability when disease and bolting are not factors. This is that portion of the variability that the sugar beet producer attempts to control through better agronomic practices. The range in tons of available sugar per acre is from 2.693 to 5.000, in tons of beets per acre is from 20.11 to 37.13, in percentage of sucrose is from 12.28 to 19.24, and in coefficient of apparent purity from 80.94 to 89.42. That the variation between individual farms is even greater cannot be doubted.

Even though much is already known concerning those factors causing variability, much remains to be learned and can be learned by well-designed and executed agronomic experiments. For example, the effects of dates of planting, irrigation practices, fertilizers, and other cultural practices upon the percentage sucrose is not definitely known. The need for such information is emphasized by the range of the means for this character.

In designing a plant breeding program and in designing agronomic experiments it is helpful, if not essential, to have in mind the inter-relationship of the various characters concerned. The relationship between tons of available sugar per acre as calculated in the variety test plots from 1939 to date is evident, since tons of available sugar per acre is the product of tons of beets per acre times percentage sucrose times coefficient of apparent purity. Such being the case information as to the relative importance of these three characters and their inter-relationship is of decided value. The data from which table 4 was calculated furnish considerable information on this point in respect to the territory in which the Spreckles Sugar Company operates.

The method of multiple regression was used to determine the relative importance of tons of beets per acre, percentage sucrose and coefficient of apparent purity. The standard regression coefficients were 0.9688 for tons of beets per acre, 0.8145 for percentage sucrose, and 0.1660 for coefficients of apparent purity. These regression values show that tons of beets per acre and percentage sucrose are about equally effective in determining tons of available sugar per acre, the former being only 1.2 times as effective as the latter. But tons of beets per acre and percentage sucrose are considerably more important than the coefficient of apparent purity in determining tons of available sugar per acre, the corresponding numerical values being 5.8 and 4.9, respectively. This information permits placing the proper emphasis on these characters in a breeding program and in recommending certain agronomic practices.

Of considerable importance to both breeding and agronomic procedure is the relationship betwen tons of beets per acre, percentage sucrose, and coefficient of apparent purity. To determine this, analyses of covariance were made. Only 18 percent of the variances of tons of beets per acre and percentage sucrose was accounted for by covariance. The relationship was negative. This means that some of the environmental conditions were favorable to one of these characters but not to the other. Looking at the brighter side, the 82 percent of the variances that was not accounted for by covariance would indicate that some of the environmental conditions probably were favorable to both. Such conditions prevailed in the tests planted at King City in March 1941, since both a high yield and high percentage of sucrose were obtained. The same was true of the Woodland planting for January 1939. The relation between tons of beets per acre and the coefficient of apparent purity was negative, also; and 24 percent of the two variances was accounted for by covariance. It is evident that these two characters are not mutually exclusive; certain conditions may be favorable to both even though the predominating tendency is for an increase in one to be accompanied by a decrease in the other. The relationship between the percentage sucrose and the coefficient of apparent purity was positive, and 55 percent of the variances of these two characters was accounted for by covariance. This means that a number of those environmental factors favorable to one character were also favorable to the other.

These facts clearly point to the need of agronomic experiments to determine what conditions produce such results. Indications from these data are that early dates of planting may be favorable to both characters. If so, breeding a variety more resistant to those conditions causing bolting is desirable so that earlier plantings can be made.

Discussion

These data rather conclusively show that the varieties being grown in those areas in which the Spreckels Sugar Company operates fall into three main groups as follows: Those possessing a high degree of resistance to the attacks of the virus causing curly top, those possessing a moderate degree of resistance to the attacks of the organism causing downy mildew; and those possessing resistance to the conditions causing bolting. The first group is designated as the "curly top resistant group" and includes U. S. 22, U. S. 33, and Improved U. S. 33. The second is designated as the "downy mildem resistant group" and includes U. S. 15 and Old Type (R & G).

Breeding Problems

The data from the varietal trials aid in evaluating the breeding problems. Since varieties with a high degree of resistance to the

attacks of the virus causing curly top are now available, it is advisable at this time to shift some of the emphasis to improving other characters and to obtain varieties recombining desirable characters.

Although varieties with some degree of resistance to *P. schachtii* are being grown, too frequently this disease still exacts a large toll from the producer of sugar beets. In fact, obtaining a satisfactory degree of resistance to the attacks of *P. schachtii* is at present one of the most important breeding problems in the area in which the Spreckels Sugar Company operates.

Of most importance is a greater resistance to those environmental factors conducive to bolting. U. S. 15 rates highest in this respect but in some years when this variety is planted in December and January, yields of sugar per acre are materially reduced by too many plants bolting. Also, there is definite need for a variety that can be planted in October and November without undue losses occurring because of bolting. Such early plantings may materially increase the yield of sugar per acre, and in the Bakersfield area early planting is particularly desired by growers so that the growing of sugar beets will fit more advantageously into farming operations. In reality such a variety of sugar beet would receive a hearty welcome over the entire territory in which the Spreckels Sugar Company operates.

Under the environmental conditions of the San Joaquin, Sacramento, and Salinas Valleys any differences between varieties in the production of tons of sugar per acre were found to be due to differences in the ability of varieties to resist the attacks of disease-causing organisms or to resist those environmental factors conducive to bolting. This fact points to the desirability of emphasizing yielding ability in the breeding program. Apart from disease and bolting, increases in yielding ability obtained by limiting the material to the varieties and selections included in these tests may be expected to be small. Hence, the need for including a greater diversity of genetic material is evident.

Much can be gained by recombining resistance to the attacks of the virus causing curly top, resistance to the attacks of *P. schachtii* (downy mildew), and resistance to those factors causing boilting. A variety possessing these characteristics could be planted anytime from December to the end of the planting season without undue risks of losses from disease or bolting.

Acknowledgments

Acknowledgments are due the members of the Agricultural Department of the Spreckels Sugar Company for collecting the data.

Report on Tests in 1945 of U. S. 215 x 216 and Other Varieties from Sugar Beet Leaf-Spot-Resistance Breeding Investigations of the U. S. Department of Agriculture

G. H. Coons, Dewey Stewart, G. W. Deming, J. O. Gaskill, R. W. Henderson, J. G. Lill, and S. B. Nuckols[1]

Agronomic evaluation tests were conducted in 1945 with the first and third releases of U. S. 215 x 216, and with other varieties obtained in the federal leaf-spot-resistance breeding project. Tests at 13 locations as conducted by members of the staff of this Division in cooperation with Agricultural Experiment Stations and by cooperators in the beet sugar industry are reported. The cooperators in research organizations of the beet sugar industry who contributed data are as follows: Pere A. Reeve, Farmers' and Manufacturers' Beet Sugar Association (tests at Holgate, Ohio, and Ogden Center, Mich.); C. W. Doxtator, American Crystal Sugar Company (tests at Rocky Ford, Colo., Wood river, Nebr., and Mason City, Iowa); and C. E. Cormany, Holly Sugar Corporation (test at Sidney, Mont.). Two varieties were included in tests at Fort Morgan and Brush, Colo., by H. E. Brewbaker and R. L. Bush. The data for these two varieties are not included in this summary.

The distribution of the 13 tests summarized was as follows: four in Colorado, one each in Wyoming, Montana, Nebraska, Iowa, Minnesota, and Ohio, and three in Michigan.

In 1945 only minor damage was caused by leaf spot *(Cercospora beticola)*. In two of the tests (Fort Collins and Rocky Ford) epidemic conditions were artificially produced by means of overhead sprinklers. At Wood River, Nebr., leaf spot occurred naturally in fairly severe form. The comparisons in 1945, as in 1944, therefore evaluate chiefly the agronomic characters of the varieties under conditions in which leaf spot resistance made relatively minor contribution. As pointed out in 1944 for a similar situation, data obtained when disease impact is below normal assist in appraisal of the general utility of leaf spot resistant introductions, but may show up some weaknesses in resistant varieties. Since exposures vary from year to year in the sugar beet growing districts, a resistant variety must not only be superior in seasons when leaf spot is severe, but it needs also to yield satisfactorily in non-leaf-spot seasons. At the present status of

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sugar beet breeding, if a resistant variety does not depart, in a season without leaf spot, very significantly from the general mean in a test or a series of tests, such performance probably represents reasonable expectation.

In previous comparative tests U. S. 215 x 216 had shown definite superiority over U. S. 200 x 215; in turn the variety designated as Improved U. S. 215 x 216 (SP 1-8-00) was found superior to the parent variety. The practice has now been adopted with the U. S. curly top resistant varieties of designating a reselection from a variety improved in resistance or other qualities as second, third, or other numbered release of the parent number, instead of designating it as "Improved". In line with this practice, "Improved" U. S.

Table 1.—Comparison of first and third releases of U.S. 215 x 216 (SP 2-1-00 vs. SP 4-7-00) in 13 evaluation tests of U. S. leaf spot resistant varieties as conducted by Division of Sugar Plant Investigations and its cooperators. (Data given are averages of eight replicates unless otherwise noted.)

Location	Contributed by	Acre yield					
		Gross sugar		Roots		Sucrose	
		First release	Third release	First release	Third release	First release	Third release
		(Pounds)	(Pounds)	(Tons)	(Tons)	(Percentage)	(Percentage)
Colorado							
Ft. Collins sprinkler	J. O. Gaskill	2,724	3,080	9.64	10.06	14.14	15.34
Ft. Collins College	G. W. Deming	3,680	3,595	13.04	11.80	14.12	15.22
Ault	J. O. Gaskill	5,084	5,276	14.97	14.47	16.98	18.22
Rocky Ford	C. W. Doxtator	4,344	4,676	14.35	14.10	15.17	16.58
Nebraska							
Wood River*	C. W. Doxtator	5,086	4,975	14.72	14.07	17.28	17.80
Iowa							
Mason City*	C. W. Doxtator	3,111	2,841	10.20	9.13	15.27	15.57
Wyoming							
Torrington	S. B. Nuckols	4,866	4,364	13.56	11.81	17.94	18.33
Montana							
Sidney	C. E. Cormany	3,040	2,802	12.54	11.09	12.11	12.60
Minnesota							
Mankato	R. W. Henderson	3,036	2,898	9.36	8.76	16.19	16.55
Michigan							
East Lansing	J. G. Lill	2,198	1,722	7.20	5.46	15.32	15.88
Merrill	J. G. Lill	3,446	3,291	10.12	9.76	16.08	16.87
Ogden Center†	Perc Reeve J. G. Lill	4,592	4,904	13.89	14.61	16.41	16.81
Ohio							
Holgate	Perc Reeve J. G. Lill	2,366	2,330	8.11	7.74	14.52	15.02
Average		3,659	3,596	11.72	10.99	15.50	16.21

*5 replications
†7 replications

215 x 216, as represented by SP 1-8-00 tested in 1944, is now designated as the second release, or U. S. 215 x 216/2. In 1945 a third release of U. S. 215 x 216 was tested as SP 4-7-00. This will be designated as U. S. 215 x 216/3.

The three releases of U. S. 215 x 216 represent valuable additions to the list of American sugar beet varieties. All have high resistance to leaf spot. U. S. 215 x 216/3 is very outstanding in this respect and is indicated for use in all districts having records of severe leaf spot exposure. In comparison with the parent variety it classifies definitely as a sugar type.

In view of the depressing effects of leaf spot on sucrose percentage this capacity to produce high sucrose, even under leaf spot exposure, may be very important. U. S. 215 x 216/1 or /2 will probably continue to be utilized as the all-around leaf spot resistant types, high

Table 2.—Summary* of gross sugars and root weights (acre yields) and of sucrose percentages for the varieties included in 13 replicated tests in 1945. Three records from similar tests in 1944 are given for comparison. The data for the individual varieties are also expressed as percentages of the performance of U. S. 215 x 216/1 (SP 2-1-00), for the indicated year.

SP Seed No.	Description	Year of test	Acre yield: Gross sugar: Average	Acre yield: Gross sugar: As percentage of 2-1-00	Acre yield: Roots: Average	Acre yield: Roots: As percentage of 2-1-00	Sucrose: Average	Sucrose: As percentage of 2-1-00
			Pounds	Percent	Tons	Percent	Percent	Percent
2-1-00	U.S. 215 x 216/1	1945	3,659	100.0	11.72	100.0	15.50	100.0
		1944	4,434	100.0	13.24	100.0	16.81	100.0
4-7-00	U.S. 215 x 216/3	1945	3,596	98.3	10.99	93.8	16.21	104.6
3-1834-00	Synthetic variety	1945	3,975	108.6	12.99	110.8	15.27	98.5
		1944	4,854	109.5	14.47	109.3	16.87	100.4
4-8-0	Synthetic U.S. 215 x 216 x Cesena	1945	3,864	105.6	12.17	103.8	15.82	102.1
3-3011-0	Previous generation of above	1944	4,622	104.2	13.48	101.8	17.23	102.5
4-1836-00	Synthetic variety	1945	3,872	105.8	12.24	104.4	15.76	101.7
4-6-00	U.S. 215 (Imp.) x SP 8-270-0	1945	4,060	111.0	13.28	113.3	15.23	98.3
4-5-0	Synthetic check (Seed of 9 European brands was pooled. This is second increase without selection from pool.)	1945	3,793	103.7	12.26	104.6	15.43	99.5
	Local variety†	1945	3,789	103.6	12.36	105.5	15.31	98.8

*Locations at which the tests were conducted and the names of those contributing data are shown in table 1.

†"Local variety" was Great Western in four tests (GW 59 in 2 tests); American 1 or 3 in four tests; Imperial 40 in four tests and Midwest in one test.

in root yield and moderately high in sucrose, with U. S. 215 x 216/3 being allocated to the more seriously affected districts. The results obtained with the first and third releases of U. S. 215 x 216 at 13 locations are shown in table 1.

In table 2 a summary for 1945 of the results for all varieties tested is given, together with an expression of these results in terms of U. S. 215 x 216/1. Insofar as the same variety was included in last year's tests, the 1944 data are included.

The performance of Synthetic Check (SP 4-5-0) in the 1945 tests deserves consideration. In a year without serious and general leaf spot attack, this variety, a composite of nine European brands, gave a greater sugar production, on the average, than U. S. 215 x 216, and as good an average performance as the local varieties, product of breeding work of American beet sugar companies. It was exceeded in sugar production by synthetic varieties and by one single cross in which leaf spot resistance was sacrificed for greater tonnage.

These considerations seem to point to the necessity for increased emphasis on breeding for specific adaptation, including resistance to disease, and the combining of these factors with those influencing productiveness. When such adaptations are obtained as stabilized characters in inbred lines, then through utilization of the male sterility factor it may be possible to produce 100 percent hybrids that are high yielding and carry the other desired characters.

Heterosis in Sugar Beet Single Crosses

DEWEY STEWART, JOHN O. GASKILL and G. H. COONS[1]

The investigations by Stewart, Lavis, and Coons (*5*)[2] on hybrid vigor in sugar beets were based upon 41 F_1 hybrids that were compared in replicated field tests with the inbred parents and with a commercial brand of sugar beets for root weight, sucrose percentage, and sugar production. The breeding material employed did not permit F_1 plants to be differentiated at thinning time from selfs. However, with many of the populations identification of F_1 plants, chiefly by foliage characteristics, was attempted shortly before harvest. Whenever seed collected from the strains entering a cross had not been separately kept according to seed-bearing strain, the progeny was evaluated without attempt to eliminate selfs. In 31 of 41 cases tested, root weight of the hybrid was significantly greater than the root weight of parent strains appropriate for the comparison. The average gain in root weight of hybrid over parental mean was 42.5 percent, but the authors recognized that this percentage is greatly influenced by the relative yielding abilities of the inbreds entering a given cross. The average sucrose percentage of the hybrids was slightly lower than the average of the parent inbreds, but the difference was not significant. In the tests reported, effects attributable to resistance to leaf spot (*Cercospora beticola* Sacc.) of certain inbreds or hybrids could not be separated from effects associated with vigor of hybridity, *per se*. It is considered, in general, that the performances of the hybrids when compared, either with maternal parent, with the mean of parents, or with the commercial brand, were so consistently superior throughout the tests that adequate evidence of heterosis was furnished.

For continuation of the study of heterosis in sugar beets, hybrids produced from inbreds obtained in the sugar beet leaf spot resistance breeding investigations of the Division were utilized. The inbreds under consideration are probably very superior with respect to root weight, sucrose percentage and other characters to those previously mated for hybrid-vigor studies. Eight inbreds had been selfed for three or more generations, three for two generations, one for one generation. Two mass selected varieties were included, one (Synthetic Check) as a top-cross parent, the other (U. S. 22) as a maternal parent.

The experimental work to be reported is, therefore, based upon inbreds of entirely different potentialities. In some other respects the experiments differ from the earlier work. The known inheritance

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[1]Division of Sugar Plant Investigations, Bureau of Plant Industry, Soils, and Agricultural Engineering, Agricultural Research Administration, U. S. Department of Agriculture.

[2]Italic numbers in parentheses refer to literature cited.

of hypocotyl color (*4*) was made use of to identify hybrids in the progenies obtained from the various matings. A single dominant factor, R, has been shown to bring about pink hypocotyl color of seedlings as well as pink color in the bud scales of mature sugar beet roots. If a plant that is double recessive for this color character (rr) is pollinated with pollen from a plant carrying the dominant character, either as RR or Rr, the pink hypocotyl color or pink color in the apical bud identifies F_1's in the progeny. The results reported here deal entirely with hybrid populations of the various crosses that were identified in this way. The experimental work was done in practical absence of leaf-spot attack so that effects of the disease, either in depressing yields of susceptible varieties or in permitting leaf spot resistant varieties to show relatively better yields than susceptibles, were avoided.

Methods

Source of Seed.—The hybrid sugar beet seed for the experiments was produced in seed plots designated as "master crossing plots" in which several to many inbred strains, double recessive for hypocotyl color (rr), were exposed to pollen from a single "master" strain of RR or Rr type. In the seed plot all odd-numbered rows were planted with RR (or Rr) sugar beet roots of a single inbred strain or of a commercial type. This required that roots having pink or red apical buds be chosen from this pedigree group to plant these rows. Green hypocotyl plants (rr) of a number of inbred strains of sugar beet were set out as groups in the even-numbered rows. In practice this simply required selection of roots whose apical buds did not show any indication of pink or red coloration. Pollination could occur among all the strains represented in the plot, but the only source of the R gene was from the "master" strain planted in the alternating rows. Seed was harvested separately from the green hypocotyl strains. For most of the strains the roots planted in the seed plot were essentially unselected and comprised the general run for the strain concerned. With strains heterozygous for the hypocotyl color character, it was, of course, necessary to pick either green or pink hypocotyl plants according to the particular requirement to be met.

Field Plot Methods.—The hybrids as obtained from the master crossing plots were evaluated in comparison with the parental sugar beet strains and Synthetic Check in tests conducted at Ault, Colo. Plot techniques in general use in sugar beet experiments were followed. In 1942, 32 varieties, including hybrids, inbreds, U. S. 22, and Synthetic Check, were grown in an 8-times-replicated experiment of Equalized Random Block design. However, one entire replication of 32 plots was deleted because of field irregularity, and the results were

analyzed statistically as a randomized block design with seven replications. In 1943, 40 varieties including hybrids, inbreds, and Synthetic Check were grown in an 8-times replicated experiment, also of Equalized Random Block design. The entire experiment was harvested and the results were analyzed statistically by the analysis of variance method appropriate for this design.

Individual plots were four rows wide and 23 to 24 feet long, a net row length of 40 to 42 feet being harvested. The rows were 20 inches apart. The fields were cross marked, before thinning, to facilitate accurate spacing of plants at 12-inch intervals in the row.

Plots planted with seed harvested from the green bud mother roots of the master crossing plots were thinned to leave identified (pink hypocotyl) hybrids insofar as possible. Plots planted to inbreds or varieties such as Synthetic Check or U. S. 22 were thinned without regard to hypocotyl color. At harvest, data were taken only from competitive beets from the inner rows of each plot. A plant was judged to be competitive if its immediate neighbors in the same row and in the rows to the right and left were in approximately their proper places. Plants judged to be non-competitive were not harvested. In plots containing F_1 hybrids all roots were examined after they were lifted, and those showing pink or red color at the bases of the petioles or in the scales of the apical buds were separated from those not showing such color. The latter were probably also hybrid, but the pollen parent could not be positively identified. The records for F_1's here reported are based entirely upon roots identified as described.

From the average root weight as obtained from the washed roots of a given plot, the yield for 100 percent stand was computed to the acre basis. Sucrose percentage was determined by the Sachs-LeDocte method. In the 1942 tests the roots from a plot were divided at random into two groups of approximately the same number of roots, and from each group a composite pulp sample was obtained. In the 1943 tests 25 roots were taken at random, and a single composite pulp sample was obtained. Analyses for sucrose percentage were made in duplicate on this pulp. If the two readings were not in close accord, new analyses were made on a remnant pulp sample that had been held in a refrigerator pending the checking of the pairs of sucrose readings.

Experimental Results

The pollen parents of the hybrids in both tests were U. S. 215, U. S. 216, and Synthetic Check, designated in the tabulation as "A", "B", and "Syn. Check," respectively. U. S. 215 is an inbred that is characterized by its high root yield. The sucrose percentage of the roots is about average in comparison with the general sucrose range of sugar beet varieties. The root yield, however, overcompensates for

the moderate sucrose quality, so that this inbred produces more sugar per acre than the majority of commercial varieties with which it has been compared. It has only moderate resistance to leaf spot. U. S. 216, on the other hand, classifies as a high sucrose type. The superior sucrose percentage of U. S. 216, in comparison with commercial varieties, largely compensates for its root yield, which may fall significantly below that of commercial varieties with which it has been compared. U. S. 216 is very high in leaf spot resistance. U. S. 215 and U. S. 216 are components of U. S. 215 x 216, the leaf spot resistant variety introduced by the Division (*2*). To produce this variety, equal quantities of seed of the two inbreds are pooled and a seed crop is produced from the mixture by the field-overwintering method. Therefore the seed obtained, designated as U. S. 215 x 216, actually consists of the single-cross hybrid plus seed of the two parental strains. The variety designated as Synthetic Check was obtained by pooling equal quantities of seed of nine European brands of sugar beet and producing a seed crop in New Mexico by the field-overwintering method from this mixture. As a top-cross parent it may be considered to sample the general run of European commercial brands of sugar beet. In tests conducted over a number of years by the Division, Synthetic Check has given a performance equivalent to the best European tonnage types. In the absence of leaf spot it is a high-yielding variety, moderately high in sucrose, and is capable of producing a fairly high yield of sugar per acre. It therefore can serve as a comparator for appraisal of the various hybrids in terms of performance of European tonnage varieties.

In 1942, hybrids of U. S. 22 and of five inbred strains with the three master strains were evaluated. In 1943, hybrids of seven inbred strains with the three master strains were tested. The inbreds used as maternal parents are designated in the tabulations with capital letters. The symbols are identified in table 1, where, to complete the record, details of the pedigrees of the inbreds are given. The 1929 seed number is cited in the table to permit connecting certain strains with breeding lines that have been listed elsewhere (*1*).

It is probable that the inbred designated as B′ and used as maternal parent did not differ appreciably from Inbred B used as pollen parent. The mating B′ x B, is essentially sibbing and need not be considered. Hence, in the two tests a total of 35 hybrids were studied, 3 of the 35 occurring in both tests. With respect to the pollen parents, the hybrids fall into groups of 12, 11, and 12, corresponding to strains A, B, and Synthetic Check, respectively. Twenty-one of the hybridizations are between inbred strains, 11 are top crosses, and 3 are hybrids of U. S. 22 with the 3 master strains.

Table 1.—Description of inbred varieties and of economic varieties used in the tests in 1942 and 1943.

Strain or variety					
Code designation used in text	Name of variety	Sugar Plant Inv. seed number	Generations selfed	Source or pedigree designation	1929 seed number
		Pollen Parents			
A	U. S. 215	9-294-0	6	*1846	{4793-29
B	U. S. 216	9-1007-0	4	*1833	{4796-29
Synthetic Check	Commercial	F. C. Acc. 1055	0	European Brands†	4516-29
		♀Parents			
B'	U. S. 216	1-1007-0	4	*1833	4516-29
D	....	1-1024-0	4	*2140	4874-29
D'	....	1-1025-0	5	*2140	4874-29
E	....	1-1001-0	7	*1513	4780-29
F	....	1-1004-0	7-8	*1732-3	(7489-24)
R	....	0-1016-0	6	*1991	3444-29
S	....	2-1020-0	2 or more	La Royale‡	
T	....	2-1018-0	1	Old Type‡	
U	....	2-1016-0	3	Pioneer‡	
V	....	2-1014-0	2	Schreiber‡	
W	....	0-1043-0	2	Complex* hybrid	(20416-08)
U. S. 22	U. S. 22	SL 722	0	Salt Lake City, Ut.	

*The strains indicated were obtained from mass selected breeding stocks received in 1915 by W. W. Tracy, Jr., from F. J. Pritchard. There is no history of selfing prior to Tracy's work, 1915-1929. The old accession numbers were retained in the records as a convenient designation for the lines.

†Synthetic Check as used in these tests was produced by pooling equal quantities of seed of 9 European brands of sugar beet and growing a seed crop from the mixture.

‡European commercial brands of sugar beet.

♀A mass selected curly top resistant variety obtained from Dr. F. V. Owen.

The data in tables 2 and 3 may first be considered to determine the general effects of hybridity. It is to be noted that root weights of the hybrids exceed the mean root weights of the respective parents 30 times out of a possible 38. In Sucrose percentage, the hybrids exceed the parental means 28 times out of 38. In sugar per acre, the hybrids exceed the parental means in 32 of the 38 comparisons. If the data for these attributes are analyzed by Student's method as a series of paired comparisons, the hybrids, as a class, are found to be significantly superior to the parental means, considered as a class.

It is possible also to make various other group comparisons. Comparisons in terms of the mother line afford very decisive evidence of the vigor of hybridity. In table 2 the average percentage sucrose for six hybrids having A as pollen parent is significantly below the average for the six mother parents. However, both the average root yield and the average gross-sugar yield for the six hybrids are significantly above the corresponding means for the mother strains. The

Table 2.—Comparison of 17 hybrids and of their respective parent strains for root and sugar yields and for sucrose percentages. Similar comparisons of the hybrids with Synthetic Check are also given: Ault, Colo., 1942. (Data for individual inbreds and hybrids are given as 7-plot averages.)

Inbred or hybrid variety	Acre-yield of roots			Sucrose percentage			Acre-yield of gross sugar		
	Actual yield	As percent of parents	As percent of Syn. Check	Actual reading	As percent of parents	As percent of Syn. Check	Calculated yield	As percent of parents	As percent of Syn. Check
	Tons	Percent	Percent	Percent	Percent	Percent	Tons	Percent	Percent
Synthetic Check	15.77	....	100.0	14.4	....	100.0	2.27	....	100.0
U. S. 215 A	18.09	....	114.7	13.6	....	94.4	2.47	....	108.8
U. S. 216 B	12.72	....	80.7	15.8	....	109.7	2.00	....	88.1
Mean (a) ♂ parents	15.53	....	98.5	14.6	....	101.4	2.25	....	99.0
Inbred B'	14.29	....	90.6	16.3	....	113.2	2.33	....	102.6
Inbred D	17.29	....	109.6	13.4	....	93.1	2.32	....	102.2
Inbred D'	16.25	....	103.0	14.2	....	98.6	2.30	....	101.3
Inbred E	13.69	....	86.8	15.3	....	106.3	2.10	....	92.5
Inbred F	12.65	....	80.2	15.3	....	106.3	1.94	....	85.5
U. S. 22	15.45	....	98.0	14.7	....	102.1	2.28	....	100.4
Mean (b-1) 6♀ parents	14.94	....	94.7	14.9	....	103.3	2.21	....	97.4
Mean (b-2) 5♀ parents*	15.07	....	95.5	14.6	....	101.3	2.19	....	96.4
B' x A	16.53	102.1	104.8	15.4	103.0	106.9	2.58	107.5	113.7
D x A	19.51	110.3	123.7	14.0	103.7	97.2	2.73	114.0	120.3
D' x A	16.37	95.3	103.8	13.6	97.8	94.4	2.23	93.5	98.2
E x A	17.19	108.2	109.0	14.2	98.3	98.6	2.45	107.2	107.9
F x A	15.76	102.5	99.9	13.8	95.5	95.8	2.18	98.9	96.0
U. S. 22 x A	18.03	107.5	114.3	13.9	98.2	96.5	2.51	105.7	110.6
Mean (c-1) 6 hybrids	17.23	104.3	109.3	14.2	99.4	98.2	2.45	104.5	107.8
Mean (c-2) 5 hybrids*	17.37	104.8	110.1	13.9	98.7	96.5	2.42	103.9	106.6
B' x B**	(12.90)	(95.5)	(81.8)	(16.1)	(100.3)	(111.8)	(2.08)	(96.1)	(91.6)
D x B	16.94	112.9	107.4	14.8	101.4	102.8	2.51	116.2	110.6
D' x B	15.09	104.2	95.7	15.3	102.0	106.3	2.31	107.4	101.8

Table 2—Continued)

Inbred or hybrid variety	Acre-yield of roots			Sucrose percentage			Acre-yield of gross sugar		
	Actual yield	As percent of parents	As percent of Syn. Check	Actual reading	As percent of parents	As percent of Syn. Check	Calculated yield	As percent of parents	As percent of Syn. Check
	Tons	Percent	Percent	Percent	Percent	Percent	Tons	Percent	Percent
E x B	15.11	114.4	95.8	16.8	108.0	116.7	2.54	123.9	111.9
F x B	14.82	116.8	94.0	16.3	104.8	113.2	2.42	122.8	106.6
U. S. 22 x B	15.41	109.4	97.7	15.9	104.3	110.4	2.45	114.5	107.9
Mean (d-1) 6 hybrids**	.....	.....	.....	.....	.....	.....	.....	.....	.....
Mean (d-2) 5 hybrids*	15.47	111.5	98.1	15.8	104.1	109.9	2.45	117.0	107.8
B' x Syn. Check	14.97	99.6	94.9	15.9	103.6	110.4	2.38	103.5	104.8
D x Syn. Check	16.96	102.6	107.5	14.3	102.9	99.3	2.42	105.4	106.6
D' x Syn Check	16.07	100.4	101.9	14.4	100.7	100.0	2.30	100.7	101.3
E x Syn. Check	15.31	103.9	97.1	15.4	103.7	106.9	2.36	108.0	104.0
F x Syn. Check	15.72	110.6	99.7	14.5	97.6	100.7	2.29	108.8	100.9
U. S. 22 x Syn. Check	14.93	95.6	94.7	14.5	99.7	100.7	2.16	94.9	95.2
Mean (e-1) 6 hybrids	15.66	102.1	99.3	14.8	101.4	103.0	2.32	103.6	102.1
Mean (e-2) 5 hybrids*	15.80	102.6	100.2	14.6	100.9	101.5	2.31	103.6	101.6
Diff. required for significance, odds 10:1—									
Between individual inbreds or hybrids	1.84	.....	11.7	1.1	.....	7.6	0.34	.....	15.0
Between hybrids and mean of parents	1.59	.....	.....	0.96	.....	.....	0.29	.....	.....
Between means of 5	0.82	.....	5.2	0.50	.....	3.5	0.15	.....	6.6
Between means of 6	0.75	.....	4.8	0.45	.....	3.1	0.14	.....	6.2

*Inbred B' and its hybrids were omitted in computation of means b-2, c-2, d-2, and e-2.
**Since B' x B is not a true hybrid, mean d-1 is not comparable with means b-1, c-1, and e-1.

means for the five hybrids having B as pollen parent are significantly higher than the corresponding means for the maternal parents in both sucrose percentage and gross-sugar yield. In average yield of roots, also, these five hybrids are higher than their parents but not significantly so. The average sucrose percentage for the six hybrids stemming from Synthetic Check as pollen parent is practically identical with that of the six mother strains, but in average root yield and gross-sugar yield these hybrids exceed the mother parents by amounts which closely approach significance.

In table 3, with but one exception, the averages for each group of seven hybrids are significantly above the corresponding averages for the seven mother parents in root yield, sucrose percentage, and gross-sugar yield. The only exception is the average sucrose percentage for the hybrids involving paternal parent A. This average is below that of the mother strains but not significantly so.

If comparisons are made on the basis of the performance of Synthetic Check, it will be noted that the three pollen parents average in root weight only 98.5 and 95.1 percent of this standard, the depression in average yield being traceable entirely to U. S. 216. The inbreds and U. S. 22 used as mother parents in the 1942 tests and the inbreds used as mother parents in the 1943 tests, average, in root weight, respectively, 94.7 and 95.2 percent of Synthetic Check. Only four maternal inbreds have higher root yields. None is significantly higher. The mean root weights of the hybrids in tables 2 and 3 are not in any case significantly lower than the root weight of Synthetic Check; when A is pollen parent the mean weights are substantially if not significantly higher. In sucrose percentage, it is probable that the means of hybrids in table 2 or 3 do not differ significantly from Synthetic Check except when Inbred B was the pollen parent (both tables) and when Synthetic Check was the pollen parent (table 3 only). The comparisons for sugar per acre are of especial interest. As an average, the hybrids reported in table 2 are considerably better than Synthetic Check where either A or B was the pollen parent but differ very little from Synthetic Check where that variety is shown as the pollenizer. The averages for the hybrids reported in table 3 are all substantially higher in sugar production than Synthetic Check.

The evidence clearly indicates that, as a result of heterosis, hybrids may show increased root weight, higher sucrose percentage, and consequently greatly augmented sugar production over what is indicated by averaging the results obtained from the parental strains. Similarly, the hybrids tend to exceed the maternal strains in productiveness.

Whether the increase in productivity, attributable either to im-

Table 3.—Comparison of 21 hybrids and of their respective parent strains for root and sugar yields and for sucrose percentages. Similar comparisons of the hybrids with Synthetic Check are also given: Ault, Colo., 1943. (Data for individual inbreds or hybrids are given as 8-plot averages.)

Inbred or hybrid variety	Acre-yield of roots			Sucrose percentage			Acre-yield of gross sugar		
	Actual yield	As percent of parents	As percent of Syn. Check	Actual reading	As percent of parents	As percent of Syn. Check	Calculated yield	As percent of parents	As percent of Syn. Check
	Tons	Percent	Percent	Percent	Percent	Percent	Tons	Percent	Percent
Synthetic Check	16.41	....	100.0	14.79	....	100.0	2.426	....	100.0
U. S. 215 A	17.17	....	104.6	14.54	....	98.3	2.505	....	103.3
U. S. 216 B	13.23	....	80.6	16.10	....	108.9	2.146	....	88.5
Mean (a) ♂ parents	15.00	....	95.1	15.14	....	102.4	2.350	....	97.3
Inbred –R	13.36	....	81.4	15.77	....	106.6	2.117	....	87.3
Inbred –D	16.15	....	98.4	15.23	....	103.0	2,468	....	101.7
Inbred –S	16.64	....	101.4	15.26	....	103.2	2.556	....	105.4
Inbred –T	15.64	....	95.3	14.85	....	100.4	2.339	....	96.4
Inbred –U	17.31	....	105.5	15.83	....	107.0	2.741	....	113.0
Inbred –V	14.90	....	90.8	14.71	....	99.5	2.218	....	91.4
Inbred –W	15.36	....	93.6	14.08	....	95.2	2.183	....	90.0
Mean (b) ♀ parents	15.62	....	95.2	15.10	....	102.1	2.375	....	97.9
R x A	15.54	101.8	94.7	14.99	98.9	101.4	2.355	101.9	97.1
D x A	17.47	104.9	106.5	14.50	97.4	98.0	2.543	102.3	104.8
S x A	19.99	118.2	121.8	14.93	100.2	100.9	2.985	118.0	123.0
T x A	16.23	98.9	98.9	14.41	98.1	97.4	2.349	97.0	96.8
U x A	18.58	107.8	113.2	14.94	98.4	101.0	2.806	107.0	115.7
V x A	17.03	106.2	103.8	14.68	100.4	99.3	2.507	106.2	103.3
W x A	15.26	93.8	93.0	15.54	108.6	105.1	2.383	101.7	98.2
Mean (c) A ♂	17.16	10.45	104.6	14.86	100.3	100.4	2.561	104.9	105.6
R x B	15.62	117.4	95.2	16.65	104.5	112.6	2,606	122.3	107.4
D x B	17.34	118.0	105.7	15.96	101.9	107.9	2.773	120.2	114.3
S x B	16.26	108.9	99.1	16.14	102.9	109.1	2,628	111.8	108.3

Table 3.—Continued.

Inbred or hybrid variety	Acre-yield of roots			Sucrose percentage			Acre-yield of gross sugar		
	Actual yield	As percent of parents	As percent of Syn. Check	Actual reading	As percent of parents	As percent of Syn. Check	Calculated yield	As percent of parents	As percent of Syn. Check
	Tons	Percent	Percent	Percent	Percent	Percent	Tons	Percent	Percent
T x B	15.90	110.1	96.9	15.60	100.8	105.5	2.481	110.6	102.3
U x B	16.79	110.0	102.3	16.70	104.6	112.9	2.813	115.1	116.0
V x B	15.28	108.6	93.1	16.18	105.0	109.4	2.475	113.4	102.0
W x B	16.66	116.5	101.5	15.51	102.8	104.9	2.597	120.0	107.0
Mean (d), B ♂	16.26	112.8	99.1	16.11	103.2	108.9	2.625	116.2	108.2
R x Syn. Check	14.43	96.9	87.9	15.62	102.2	105.6	2.257	99.4	93.0
D x Syn. Check	17.15	105.3	104.5	15.39	102.5	104.1	2.641	107.9	108.9
S x Syn. Check	17.64	106.7	107.5	15.57	103.6	105.3	2.743	110.1	113.1
T x Syn. Check	15.92	99.3	97.0	15.78	106.5	106.7	2.515	105.6	103.7
U x Syn. Check	17.42	103.3	106.2	16.03	104.7	108.4	2.802	108.5	115.5
V x Syn. Check	17.40	111.1	106.0	15.20	103.1	102.8	2.690	115.8	110.9
W x Syn. Check	15.15	95.4	92.3	15.00	103.9	101.4	2.288	99.3	94.3
Mean (e), Syn. Check ♂	16.44	102.6	100.2	15.51	103.8	104.9	2.562	106.7	105.6
Diff. required for significance, odds 19:1—									
Between individual inbreds or hybrids	1.57	....	9.6	0.77	....	5.2	0.303	....	12.5
Between hybrid and mean of parents	1.38	....	....	0.68	....	....	0.266	....	....
Between means of 7 shown in table	0.60	....	3.7	0.30	....	2.0	0.116	....	4.8

proved root weight or to sucrose percentage, or to both, is economically important, depends on the heritable qualities of the parents and their interactions. The comparisons with Synthetic Check throw light on this situation. Whereas the majority of the hybrids do not differ significantly from Synthetic Check in sugar production, a few are significantly better.

Certain individual hybrids are outstanding in sugar production, namely, B′ x A, D x A, S x A, U x A, D x B, U x B, S x Synthetic Check, and U x Synthetic Check. B′ x A, or U. S. 216 x U. S. 215, is probably superior in sugar production to Synthetic Check, even in the absence of leaf spot. Its superiority rests on its slightly better root yield (4.8 percent) and its better sucrose percentage. The combined result of these factors is a gross-sugar production approaching closely to a significant difference.

Hybrids D x A and D x B are crosses of a highly productive, moderately leaf spot resistant inbred with U. S. 215 and U. S. 216, respectively. Both hybrids are outstanding in performance. The inbred D′ shown in table 2, which has the same pedigree as D but with one additional generation of inbreeding, did not duplicate this reaction. In this connection it is interesting to note that genetic material from the same line as D was utilized to produce the variety, SPI 4-6-00, that was included in the 1945 agronomic evaluation tests. The particular cross was between 8-270-0, a progenitor of D, and Improved U. S. 215. 4-6-00 produced 11 percent more sugar per acre than U. S. 215 x 216 taken as the standard (*3*).

The tests also reveal that Inbreds U and A have excellent potentialities, particularly because of the excellent root weights obtained when these inbreds are used in hybrid combinations. Both inbreds were obtained from European commercial brands but have been reselected and inbred several times. Inbred U, selected from Pioneer, is particularly impressive in its performance in that it gave hybrids with A, B, and Synthetic Check, all of which were significantly better sugar producers than Synthetic Check.

In corn investigations, top crosses have been utilized as a means for preliminary appraisal of inbreds with respect to their possible performance in hybrid combinations. The hybrids of which Synthetic Check is the pollen parent may be examined to determine whether top-cross technique applied to sugar beets would give similar indication of potentialities of inbreds. The hybrid D x Synthetic Check, reported in table 2, although not significantly better in root weight than Synthetic Check, is conspicuous among the other hybrids in its yield. The sugar per acre produced by this hybrid also is not significantly above Synthetic Check but is the highest of its group, and

likewise in crosses with A and B the mother strain D is outstanding. Inbred B′ probably would not be selected for its performance when pollinated by Synthetic Check, except for the significantly higher sucrose percentage of the hybrid as compared with Synthetic Check. The hybrid is not significantly higher in sugar production.

Inbreds reported in table 3, that from other considerations were considered outstanding, are D, S, and U. Five of the six hybrids involving these mother strains and A and B pollen parents are above Synthetic Check in root weight, two significantly so. Five of these hybrids are above Synthetic Check in sucrose percentage, and in three cases the difference is significant. In sugar production, each of the six hybrids is above Synthetic Check, significantly so in four cases. Of the three mother inbreds discussed, S and U are most outstanding as judged by sugar production of the hybrids, S x A, S x B, U x A, and U x B. Of the seven top crosses shown in table 3, only those having S and U as mother parents are significantly above Synthetic Check in sugar yield. The top cross, D x Synthetic Check, although fairly high, is not particularly outstanding. Using the top-cross technique, only S and U would be positively indicated, certain other inbreds being given only tentative consideration. It would seem, from this limited sampling, that Synthetic Check as a top-cross parent, in case there were many inbreds to evaluate, might prove very effective as a tester.

Summary

Thirty-five sugar beet hybrids obtained by mating 11 inbred strains and 1 open-pollinated variety with U. S. 215, U. S. 216, and Synthetic Check as pollen parents were studied for root yield, sucrose percentage, and sugar production under conditions in which leaf spot was not a factor. The inbred strains were relatively high yielding. Other comparisons were made with Synthetic Check, a variety known to be very high in yield when leaf spot is not a factor. As a consequence, relatively few hybrids significantly exceeded, in the attributes measured, the means of parents or Synthetic Check. As a class, however, the hybrids were significantly superior to the parents. The data were based on identified hybrids and were taken in absence of leaf spot. They are interpreted as indicating definitely that heterosis occurs in sugar beets, but that with the higher yielding inbreds, and when comparisons are based on a high yielding variety such as Synthetic Check, relatively few inbreds give outstanding performances. Synthetic Check may be of value as a tester in the application of the top-cross technique to locate the inbreds with best potentialities.

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Further Studies on Sugar-Beet Autotetraploids

F. A. Abegg, Dewey Stewart, and G. H. Coons[1]

Tetraploid forms of commercial sugar beet varieties and of certain inbred lines were compared with the respective diploid varieties or lines from which they were originally derived for (1) the economic characters, sugar production, root yield, and sucrose percentage, (2) bolting tendency, and (3) number of true seeds per seed ball.

In the production of tetraploids, colchicine-treated seedlings were selected on the basis of morphological changes induced, stomatal size, or other criteria and were grown to the flowering stage (*1*)[2]. Pollen size was determined for individual plants and was the final basis for selection of plants to produce the forms here designated as tetraploids. Previous cytological studies had determined the pollen grain size associated with doubled chromosome count. A relatively small number of tetraploid individuals (2, 4, or several) of a given variety were isolated and brought to seed. Additional generations were produced by appropriate isolations of the respective cultures.[3] If the diploid parental stock is a mass-selected commercial variety, the tetraploids that were produced necessarily represent a limited segment of the whole genetic complex of the variety. Tetraploids derived from lines inbred for several generations probably more nearly conform in genic composition to the parental 2n lines.

Experimental Work

Productivity of 2n and 4n Forms.—Tetraploids from the mass-selected varieties U. S. 22 and U. S. 23 and from the inbred line U. S. 215 were compared for economic characters with the respective diploid parental varieties in two field tests, one at Beltsville, Md. (table 1), and the other at Ault, Colo.[4] (table 2). The methods used in these tests were those commonly employed in evaluation tests with sugar beets. In the Beltsville, Md., test, sugar production from tetraploids in two out of four comparisons did not differ significantly but did differ significantly in the other two comparisons. In the Ault, Colo. test, sugar production in three out of six 2n vs. 4n comparisons did not differ significantly, but in the three other cases did differ signifi-

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[2]Italic numbers in parentheses refer to literature cited.

[3]The writers are indebted to F. V. Owen and J. O. Gaskill of this Division for making seed increases of tetraploid stocks.

[4]The test at Ault, Colo., was conducted by John O. Gaskill. Acknowledgment is made to him for the contribution of data and for his close observations on effects of freezing on the 2n and 4n forms.

Table 1.—Comparative performance of tetraploid sugar beet strains and their respective diploid parental varieties in a 7 x 7 Latin Square arrangement of plots. Plots were four rows (24 inches) wide, 30 feet long. Test at South Farm, Beltsville, Md., 1942.

Variety or strain	Pedigree number	Chromosome type	Varietal or strain averages from seven plots†			
			Calc. acre-yield		Sucrose percentage	No. of beets per 100 feet of row
			Gross sugar	Roots		
			Pounds	Tons		
U. S. 22	SL 922	2n	3541	14.48	11.66	86
U. S. 22	SL 1-26	4n	3365	14.76	10.84*	83
U. S. 22	SL 1-28	4n	2907*	11.72*	11.83	82
U. S. 23	SL 923	2n	3840	15.10	12.19	89
U. S. 23	SL 1-29	4n	3615	15.86	10.91**	83**
U. S. 215	SP 7-3000-0	2n	4739	17.19	12.83	88
U. S. 215	SP 1-1011A-0	4n	3879**	16.71	11.16**	75**
Difference required for significance						
Odds, 19:1			507	2.19	0.70	4.03
Odds, 99:1			683	2.95	0.94	5.42

†Values marked * and ** exceed, respectively, the 5-percent or 1-percent point of significance when comparisons between tetraploid strains and the related diploid stocks are made within the three varietal groups, U. S. 22, U. S. 23, and U. S. 215.

cantly. In all cases sugar production from the tetraploids was less than from the diploids.

Tetraploids SL 1-26 from U. S. 22, SL 1-29 from U. S. 23, and SP 1-1011A-O from U. S. 215 at Beltsville and at Ault, Colo. were about the same in root weight as the diploid parent. Tetraploid SL 1-28 (U. S. 22) was significantly low in yield at both places. Sucrose percentage was usually significantly lower in the tetraploids than in the corresponding diploids. Since the tetraploids did not show outstandingly increased root weights over the diploids, the effects of lower sucrose percentages were not compensated and total sugar produced tended to be low.

Close observations on the relative sensitiveness to injury by freezing of the diploid and tetraploid stocks were made by J. O. Gaskill. In the test he conducted at Ault, Colo., in 1942, a light freeze occurred September 19 and a heavy one on September 26. The first freeze damaged foliage of the 2n strains to some extent, whereas the 4n strains were considerably damaged. The second freeze caused more severe damage to foliage, especially to the 4n types. Readings on scale 0-8, in which "0" indicates no frost injury, and "8", severe injury, were made and are given in table 2. It is clear from these readings that the 4n types are far more sensitive to frost injury than are 2n types.

Table 2.—Comparative performance of tetraploid sugar beet strains and the respective diploid varieties from which they were derived: 9 x 9 Latin Square test. Plots were four rows (20 inches) wide, 28 feet long. Planted May 9, harvested September 28, 1942. Test located on Harry Clark farm, Ault, Colo., and conducted by John O. Gaskill. (Data given as nine-plot averages†.)

Variety or strain	Pedigree number	Chromosome type	Calc. acre yield		Sucrose percentage	No. of plants per 100 feet of row	Frost injury‡
			Gross sugar	Roots			
			Pounds	Tons			
U. S. 22	SL 922	2n	4,100	15.1	13.6	94	2.9
U. S. 22	SL 1-26	4n	3,700	14.9	12.4*	88**	5.6
U. S. 22	SL 1-27	4n	3,140**	13.4**	11.7**	89*	6.8
U. S. 22	SL 1-28	4n	3,000**	11.5**	13.0	90*	5.8
U. S. 23	SL 923	2n	3,820	13.6	14.0	95	3.0
U. S. 23	SL 1-29	4n	3,520	14.6	12.0**	88**	6.8
U. S. 215	SP 7-3000-0	2n	4,200	14.9	14.1	96	2.1
U. S. 215	SP 1-1011-0	4n	3,820	15.4	12.5**	94	4.6
U. S. 215	SP 1-1013-0	4n	3,740*	14.4	13.0*	87**	6.2
Difference required for significance							
Odds 19:1			440	1.1	1.0	3.9	
Odds 99:1			600	1.4	1.3	5.3	

†Values marked * and ** exceed, respectively, the 5-percent or 1-percent point of significance when comparisons between tetraploid strains and the related diploid stocks are made within the three varietal groups, U. S. 22, U. S. 23, and U. S. 215.

‡Frost injury to foliage was graded on a scale in which "0" indicates no frost injury and "8" very severe foliage injury.

Since the harvest was made 2 days following the heavy freeze, effects on yield and quality of the sugar beet roots probably were small and rather unimportant.

Bolting Tendencies in 2n and 4n Forms.—To compare the relative bolting tendency of the tetraploid with the reading of the corresponding diploid, plants of both types were started from seed at the Beltsville, Md., greenhouse. Seed was planted in 3-inch pots on January 1, 1943, and after relatively rapid growth at about 70° F. the small plants were held in an unheated greenhouse with temperatures approximating 45° F. Throughout the experiment attempt was made to have conditions equalized among varieties and between the tetraploid and diploid forms.

Normal daylight was supplemented by 6 hours of electric light (5 p. m. to 11 p. m.). The varieties were placed on four greenhouse benches, aliquots of each variety occurring at random on each bench. Transplanting to the field was done on April 2, 1943. Cold wet weather prevailed in the early part of April. The varieties, usually as sets of 16, were planted in the field so that all plants from one bench constituted a block. Distribution of varieties within the blocks was at random. The summarized data for the test are given in table 3.

Table 3.—Comparative numbers and percentages of bolters of (1) diploid (2n) sugar beet varieties and (2) their related tetraploid (4n) strains. January 1-June 12, 1943, Beltsville, Md.

Variety	Pedigree number	Description	Total No. plants (all material)	Bolters (6-19-1943) No.	Bolters (6-19-1943) Percent	Remarks
U.S. 22/2	SL 97	Parental 2n	103	6	5.8	Curly top resistant parental stock.
U.S. 22/2	F.A.A. 262 H	Derivative 4n	108	2	1.8	First generation 4n strain.
U.S. 22	SL 922	Parental 2n	103	8	7.7	Curly top resistant parental stock.
U.S. 22	SL 1-25	Derivative 4n	48	6	12.5	Second generation 4n strain.
U.S. 22	SL 1-26	do.	107	28	26.1	do.
U.S. 22	SL 1-27	do.	103	3	2.9	do.
U.S. 22	SL 1-28	do.	36	0	0.0	do.
U.S. 22	SL 200	do.	108	0	0.0	do.
U.S. 22/2 (2n) x U.S. 22 (4n)	SL 2100	3n*	188	5	2.6	All red hypoc. color types or identified 3n.
U.S. 23	SL 923	Parental 2n	108	6	5.6	Curly top resistant parental stock.
U.S. 23	SL 1-29	Derivative 4n	104	7	6.7	Second generation 4n strain.
U.S. 23	SL 1-29A	do.	108	20	18.5	do.
U.S. 23	SL 1-29B	do.	108	0	0.0	do.
U.S. 215	SP 7-3000-0	Parental 2n	104	3	2.8	Leaf spot resistant parental strain.
U.S. 215	SP 1-1011A-0	Derivative 4n	108	0	0.0	Second generation 4n strain.
U.S. 215	SP 1-1013A-0	do.	103	0	0.0	do.
U.S. 216	SP 1-16-0	Parental 2n	108	13	12.0	Leaf spot resistant parental strain.
U.S. 216	F.A.A. 264 H	Derivative 4n	108	2	1.8	First generation 4n strain.
1167	F.A.A. 150	Parental 2n	108	31	28.7	6 gener. known inbreeding.
1167	F.A.A. 154	Derivative 4n	84	1	1.2	Third generation 4n strain.

*Derived from U. S. 22/2 as 2n seed parents (r hypocotyl color) x U. S. 22 derivative first generation 4n plants as pollen parents (RR phenotype).

In 13 comparisons of the relative amounts of bolting in 2n and 4n types, the tetraploid showed less bolting in 9 cases, approximately the same amount in 1 case, and strikingly more bore bolting in 3 cases. In one of the comparisons the diploid line had been inbred six generations. It showed 28.7 bolters, whereas the tetraploid derived from it (third generation) showed only 1.2 percent. Tetraploids from in-

breds U. S. 215 and U. S. 216, similarly, showed marked drop in bolting. In the test, one triploid was included. It showed a reduced bolting tendency in comparison with the parental stock (U. S. 22). With respect to the three tetraploids showing increased bolting tendency, the notes taken March 21, 1940, when individual plants were selected to produce the tetraploids, show that the majority of the plants producing these three lots were then classed as fast bolters. It would seem plausible to assume that selection had been made toward increased bolting.

Tendency of Seed Balls of 4n Forms to have Single Germs.—In an earlier report (*2*) the senior author called attention to the morphological differences in the seed balls of 2n and 4n forms, and especially that tetraploid seed balls, although larger, contain fewer viable seeds than those from comparable diploids. It seemed desirable to explore this matter further.

Seed balls from field-grown 4n plants were passed over a 12/64 screen in order to retain only the larger seed balls. Seedling production from these seed balls was compared with that from similarly sifted seed from diploid varieties. In all cases the 4n types showed marked reduction of viable seeds per seed ball in comparison with the 2n types. As judged from comparable mature seed balls, the number of flowers that were initiated was approximately the same for the two types. Seed ball size in the tetraploids was larger than in the diploids. The data from the comparisons made with seed screened to include only the large seed balls are given in table 4.

The average number of seed balls containing a single viable seed per seed ball for four tetraploids derived from U. S. 22 or U. S. 23 was 72 percent as contrasted with 34 percent for diploid U. S. 22. Tetraploids U. S. 215, U. S. 216, and U.. S. 215 x 216 showed, respectively, 63, 76, and 58 percent seed balls with a single viable seed per ball, as compared with 24 percent for diploid U. S. 215 x 216 used as control.

Attention is called to the fact that these tetraploid seed balls have naturally about the same condition of single germness as is obtained by carefully processing diploid seed to obtain sheared, or segmented, seed.

Conclusions

The following conclusions are drawn from the tests so far conducted. Doubling of chromosomes in sugar beets has not resulted in increased productivity over that of the original diploids. The general effect seems to be production of types that are vegetative and de-

Table 4.—Seedlings per seed ball obtained from 4n and 2n types. Field-grown seed was passed over a 12/64 screen. The large seed balls thus obtained were planted in 3-inch pots filled with sterilized soil, one seed ball per pot. Counts of seedlings per pot were made after 16 days. December 3-20, 1945. Sugar Plant Greenhouse, Beltsville, Md.

Variety	Pedigree number	Chromosome type	Germination	From 308 seed balls planted			Classification of seed balls			
				Viable seed balls	Total seedlings	Seedlings per ball	1-germ	2-germ	3-germ	4-germ, +
			Percent				Percent	Percent	Percent	Percent
U. S. 22	SL 299	4n	82.1	253	386	1.53	55.7	36.0	8.3	0.0
U. S. 22	SL 1-26	4n	86.0	265	418	1.58	53.6	36.2	9.1	1.1
U. S. 22	SL 1-28	4n	39.6	122	133	1.09	91.0	9.0	0.0	0.0
U. S. 23	SL 1-29	4n	63.0	194	214	1.10	89.7	10.3	0.0	0.0
U. S. 22	SL 922	2n	76.6	242	496	2.06	34.3	34.7	23.6	6.6
U. S. 215	SP 3-1041-0	4n	84.7	261	377	1.44	63.6	28.4	8.1	0.0
U. S. 216	SP 3-1042-0	4n	54.6	168	210	1.25	76.2	22.6	1.2	0.0
U. S 215 x 216	SP 4511-0	4n	73.4	226	336	1.49	58.9	34.1	6.6	0.4
U. S 215 x 216	SP 2-1-00	2n	87.0	268	559	2.09	24.6	50.4	16.8	8.2

layed in maturing. Harvest of tetraploids at the dates customarily used for diploids may, therefore, be disadvantageous to these more vegetative types. Such handicap might be obviated by deferring harvest. However, the greater sensitiveness to frost injury limits the period that harvest of the tetraploids can be extended.

Abegg (*2*) had concluded that, since some of the 4n strains he had studied possessed good vigor, types of value to the plant breeder may be obtainable by wide application of this breeding method. The additional experience with his material confirms the earlier conclusion.

Lessened bolting tendency in tetraploids seems to be indicated by the tests. Tetraploidy may find some application with a variety that is satisfactory for a given environment except for a pronounced tendency to bolt. It is possible that the tetraploid form of such a variety would show such reduced bolting tendency as to make the variety usable in situations where its use now is precluded.

Of especial interest is the discovery that seed balls of tetraploids are prevailingly single germ in character. The data, based on seed balls screened to large size, show that the tetraploids tested give naturally about the same record as to single germness of seed balls as can be produced artificially by the most careful processing. In the shearing process there is a heavy waste of seed. There is strong possibility that seed of tetraploid forms, if otherwise satisfactory, could be used directly in mechanized operations in growing sugar beets.

Practical application of tetraploidy with sugar beets requires discovery of high yielding strains. The tests so far represent an extremely limited sampling and their outcome is not at all prejudicial to the expectation that valuable material may be produced by this technique. When such high yielding tetraploids are found, they may have additional advantages, namely, reduced bolting tendency and definite tendency toward single germness of seed ball.

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Crossing Experiments in Sugar Beet Lines

C. W. Doxtator and A. W. Skuderna[1]

Hybridization of inbred lines and of selections has been found to produce marked improvement in yielding ability in many crops. Stewart et al (*3*)[2] reported increased yields of hybrids over parent inbreds and check varieties in the sugar beet. A study of variety hybrids reported in 1942 (*2*) proved that increased yields were possible by crossing certain varieties. The present study was undertaken to determine what improvement might be obtained from the crossing of open-pollinated mother lines selected from a single variety.

Origin of Parent Lines

Root selections were made in 1939 from an elite stock of American No. 1 known as 8-406-0 (*2*). In 1940, 192 of the best of these roots were set out in a space-isolated group for seed production, and from this group some 50 plants were harvested separately as mother lines for field test in 1941. In 1940 another selection of roots was made from the same variety and in 1941, 177 roots were planted in an isolated group. From this 1941 group, 75 plants were harvested separately for mother line test in 1942. The root selections of 1940 and 1941 were made for leaf spot resistance in the field, and while the roots were in winter storage they were tested for sucrose and the largest beets with high sucrose percentage were saved for the summer groups.

Nursery plot tests of the plant progenies were made in 1941 and 1942 and significant differences were obtained for resistance to leaf spot, for sucrose percentage, and for yield of beets and sugar per acre. Only the lines which appeared most promising were selected for greenhouse crossing work. In 1941 the lines selected were Nos. 8, 26, 35, 38, and 83. In 1942 root selections of the Nos. 26 and 35 were made from greenhouse-produced seed, and from the 1942 tests the lines No. 5, 25, 28, and 33 were selected.

Experimental Methods

Selected roots of the mother lines to be used for crossing experiments were taken from the field in late October of each year, 1941 and 1942, and stored in the root storage room for a period of 9 weeks. The beets were potted in 8-inch pots and transferred to the greenhouses on January 2 of each year, 1942 and 1943. Temperatures in the greenhouse were kept between 55° and 65° Fahrenheit until February 25, after which date the temperature was allowed to go above

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[1]Plant Breeder and Manager, respectively, Beet Seed Operations, American Crystal Sugar Company.

[2]Italic numbers in parentheses refer to literature cited.

70° Fahrenheit during the daytime. Supplemental light was given during the entire night period from January 10 to March 31. These conditions produced fairly uniform bolting, flowers began to shed pollen by February 15, and by March 10 practically all plants had flowered.

In the 1942 winter season 40 beets were used from each of the 5 lines selected, and all possible cross combinations of lines were made, as well as sibs of each line. The bag switching technique (*2*) was employed for this work. An average of 20 plants (both parents) were used for each cross and for each sibbing of parent. Number 8 Kraft grocery bags were used entirely. In 1943 an average of 50 beets from each of the 6 selected lines were used and all possible combinations of crosses made, as well as sibs of each of the 6 parent lines, using the same back switching technique as was employed the previous season.

Care was taken to ensure maximum crossing of the two parents. Each pair of plants selected for crossing had to be in the same stage of flower development, and if, after bagging, one plant failed to be a good pollen producer, a better plant was selected. Bags containing less than 50 seeds were discarded at harvest as an added precaution against possible self-pollination (*2*). Seed in all bags of each cross (or sib) was then bulked for use in field trials. The seed lots produced varied from 1,500 to 5,000 seed balls and were adequate to plant the tests planned. The check variety, American No. 1 (8-406-0), and Schreiber SS, a foreign variety susceptible to leaf spot, were included in the tests. These varieties were not produced in the greenhouse but came from large bulk lots of seed.

In both seasons, 1942 and 1943, the tests were planted on the Rocky Ford Experimental Station farm. The test fields used were innoculated with leaf spot and sprinkled by a Skinner sprinkling system to ensure a leaf spot epidemic.

All cultures were planted in five replications of single-row plots in 1942. Rows were 36 feet long, spaced 20 inches apart, with beets spaced 20 inches apart in the row. In the 1943 season the same size of plot was used and the same plant spacing, but it was possible to plant 10 replications of each culture. All beets from each plot in both tests were harvested for yield and sucrose percentage.

Experimental Results

There were 10 hybrids, 5 parent lines, and the 2 check varieties, or a total of 17 cultures in the 1942 test. In the 1943 test there were 15 hybrids, 6 parent lines, and 2 check varieties, for a total of 23 cultures. The results of the 1942 test are given in table 1.

Table 1.—Performance of open-pollinated mother lines, all possible hybrids, and check varieties, Rocky Ford, Colo., 1942.

Hybrid No.	Hybrid (a x b)	Parent a	Parent b	Hybrid a x b
		Tons beets per acre		
1	8x26	15.33	15.41	18.73
2	8x35	15.33	15.89	17.47
3	8x38	15.33	11.62	17.84
4	8x83	15.33	15.17	14.48
5	26x35	15.41	15.89	20.41
6	26x38	15.41	11.62	16.58
7	26x83	15.41	15.17	18.43
8	35x38	15.89	11.62	18.55
9	35x83	15.89	15.17	18.66
10	38x83	11.62	15.17	18.58
Average		15.10	14.27	17.97
Variety parent of lines (8-406-0 Check)			14.53	
Foreign variety check			13.62	
Significant difference (odds 19:1)			3.64	
		Sucrose percentage		
1	8x26	15.84	15.18	14.94
2	8x35	15.84	14.44	13.94
3	8x38	15.84	15.14	15.72
4	8x83	15.84	14.34	15.82
5	26x35	15.18	14.44	14.64
6	26x38	15.18	15.14	14.78
7	26x83	15.18	14.34	15.10
8	35x38	14.44	15.14	14.92
9	35x83	14.44	14.34	14.68
10	38x83	15.14	14.34	15.40
Average		15.29	14.68	14.99
Variety parent of lines (8-406-0 Check)			13.84	
Foreign variety check			12.32	
Significant difference (odds 19:1)			1.01	
		Pounds sugar per acre		
1	8x26	4,860	4,671	5,602
2	8x35	4,860	4,583	4,893
3	8x38	4,860	3,508	5,605
4	8x83	4,860	4,360	4,586
5	26x35	4,671	4,583	5,967
6	26x38	4,671	3,508	4,908
7	26x83	4,671	4,360	5,555
8	35x38	4,583	3,508	5,569
9	35x83	4,583	4,360	5,470
10	38x83	3,508	4,360	5,644
Average		4,613	4,180	5,380
Variety parent of lines (8-406-0 Check)			3,991	
Foreign variety check			3,346	
Significant difference (odds 19:1)			1,113	

Despite a high standard error due mainly to very small plots and lack of replication, significant differences were obtained between hybrids and between hybrids and parent lines. As an average the 10 hybrids were highest in yield of beets and of sugar, followed by the 5 parents, with the check varieties last in yield rank. The highest yielding hybrid, 26 x 35, was significantly higher than either of the parent lines or check varieties. This hybrid was slightly lower in

sucrose than the average of the 10 hybrids, but significantly lower than only two hybrids. The lowest yielding hybrid was 8 x 83, and although its yield of beets was lower than either parent, the difference was not at significant level. This hybrid was significantly higher in sucrose percentage than four hybrids.

Since the mother lines No. 26 and No. 35 were superior parents as judged not only as a single cross but from the average yield of all four of their possible hybrids, these lines were selected for use in 1943, together with the four lines selected from the 1942 mother line tests. The data from the 1943 test are given in table 2.

In this test the hybrids, as an average, were higher in beet and sugar yield than the parent lines, and significant differences were obtained between hybrids, and between hybrids and their parent lines. Line No. 26 was significantly higher, and line No. 5 significantly lower in yielding ability than the parent variety 8-406-0. In sucrose percentage the foreign variety was significantly lower than all others except line No. 25 and hybrid 5 x 25. All sucrose percentages were lower than normal because of late planting, a severe leaf spot epidemic, and heavy rains prior to harvest.

In order to show clearly the effect of the crossing of the mother lines, a summary of all significant differences (at odds level of 19:1) was made from tables 1 and 2. This summary is given in table 3.

It is important to know whether parent mother lines producing high yields also produce high yielding crosses, since at the present time controlled crossing is not possible in commercial seed fields. Accordingly, correlation coefficients were calculated using the average yield of the two parents and the yield of the resulting hybrid. For the 25 hybrids the correlations were as follows:

$$\frac{A+B}{2} : A \times B = \begin{cases} (r = \pm 0.80 \pm 0.07 & \text{tons beets per acre.} \\ (r = \pm 0.90 \pm 0.04 & \text{sucrose percent.} \\ (r = \pm 0.89 \pm 0.04 & \text{pounds sugar per acre.} \end{cases}$$

It is apparent that in these selections when the average yield of the parent lines was high the resulting hybrid in most cases was high in yield. This is not an uncommon observation in corn (*1*). However, it is observed that because the correlation is not perfect some poor yielding hybrids could be obtained from relatively good yielding parent lines. It is of utmost importance to eliminate such lines by determining their worth in cross combination before commercial seed is made. In table 1 Lines 8 and 83 are relatively high in beet yield, but the hybrid does not have the increased yield found in hybrids made

Table 2.—Performance of open-pollinated mother lines, all possible hybrids,and check varieties, Rocky Ford, Colo., 1943.

Hybrid No.	Hybrid (a x b)	Parent a	Parent b	Hybrid a x b
		Tons beets per acre		
1	5x25	10.19	12.13	13.20
2	5x26	10.19	15.22	13.50
3	5x28	10.19	12.28	12.75
4	5x33	10.19	12.69	12.84
5	5x35	10.19	11.93	13.46
6	25x26	12.13	15.22	13.84
7	25x28	12.13	12.28	12.39
8	25x33	12.13	12.69	13.08
9	25x35	12.13	11.93	13.89
10	26x28	15.22	12.28	14.78
11	26x33	15.22	12.69	15.89
12	26x35	15.22	11.93	18.05
13	28x33	12.28	12.69	12.12
14	28x35	12.28	11.93	13.53
15	33x35	12.69	11.93	15.10
Average		12.16	12.66	13.90
Variety parent of lines (8-406-0 Check)			12.85	
Foreign variety check			12.41	
Significant difference (odds 19:1)			2.28	
		Sucrose percentage		
1	5x25	12.37	10.32	10.73
2	5x26	12.37	12.18	11.66
3	5x28	12.37	12.77	12.30
4	5x33	12.37	11.96	11.74
5	5x35	12.37	11.79	12.22
6	25x26	10.32	12.18	11.56
7	25x28	10.32	12.77	12.23
8	25x33	10.32	11.96	11.83
9	25x35	10.32	11.79	12.75
10	26x28	12.18	12.77	11.87
11	26x33	12.18	11.96	12.26
12	26x35	12.18	11.79	11.98
13	28x33	12.77	11.96	12.12
14	28x35	12.77	11.79	13.05
15	33x35	11.96	11.79	13.50
Average		11.81	11.99	12.12
Variety parent of lines (8-406-0 Check)			10.94	
Foreign variety check			9.98	
Significant difference (odds 19:1)			.94	
		Pounds sugar per acre		
1	5x25	2,548	2,508	2,880
2	5x26	2,548	3,728	3,138
3	5x28	2,548	3,155	3,160
4	5x33	2,548	3,077	3,055
5	5x35	2,548	2,819	3,306
6	25x26	2,508	3,728	3,207
7	25x28	2,508	3,155	3,084
8	25x33	2,508	3,077	3,113
9	25x35	2,508	2,819	3,576
10	26x28	3,728	3,155	3,587
11	26x33	3,728	3,077	3,941
12	26x35	3,728	2,819	4,354
13	28x33	3,155	3,077	2,979
14	28x35	3,155	2,819	3,588
15	35x35	3,306	2,819	4,079
Average		2,905	3,056	3,403
Variety parent of lines (8-406-0 Check)			2,809	
Foreign variety check			2,523	
Significant difference (odds 19:1)			636	

Table 3.—Significant increase or decrease in productivity of 25 line hybrids as compared to parent lines, Rocky Ford, Colo., 1942-1943.

Number of hybrids	Tons beets per acre	Sucrose percentage	Sugar per acre
Lower than both parents	0	0	0
Lower than one parent	0	2	0
Higher than one percent	9	6	9
Higher than both parents	3	2	4
Showing no significant difference	13	15	12
Total hybrids tested*	25	25	25

*One hybrid 25x35 was included in both 1942 and 1943 tests.

from other lines. In mass selection these lines, being high in yield, would undoubtedly be included in the breeder's stock increase.

Discussion and Conclusions

The data obtained in this study indicate that there was an appreciable amount of hybrid vigor in crosses of open-pollinated mother lines selected from the parent variety. In 1942 the average sugar per acre yield of the 5 parent lines was 4,396 pounds as compared to 5,380 pounds for the average of the 10 possible hybrids; and in 1943, 6 parent lines produced an average sugar per acre yield of 2,980 pounds as compared to 3,403 pounds for the average of the 15 possible hybrids. Of the 25 hybrids tested, 9 were significantly higher in sugar per acre yields than one parent, 4 were significantly higher than both parents, and 12 showed no significant differences. Despite the average higher yield of hybrids over parent lines, sucrose percentage was not depressed.

Significant differences were obtained between the hybrids in both seasons for sugar per acre yield. The best yielding hybrid in the 1942 tests, 26 x 35, was highest in yield rank in 1943. In correlation tests it was found that high yielding parent lines usually gave high yielding crosses, but this relationship was not perfect.

The selected mother lines, as an average, produced a beet yield not significantly higher than the parent variety. All improvement obtained was in sucrose percentage and was due mainly to the selection of lines more resistant to leaf spot. The foreign check variety was not significantly different in beet yield from the parent variety but was significantly lower in sucrose percentage because of attacks of leaf spot to which this variety was highly susceptible.

From the results obtained in this study it is apparent that some improvement in sugar per acre yields would have been obtained from making bulk increases of the five lines selected in 1941, and the six lines selected in 1942. However, by making and testing all the hybrid

progenies, a selection of lines could be made, not only on their own yielding ability but also on their ability to produce maximum hybrid vigor effects, thereby making possible a still greater improvement in yield.

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Reaction of Sugar Beet Strains to *Aphanomyces Cochlioides*[1]

R. W. Henderson and H. W. Bockstahler[2]

Several species of fungi including *Aphanomyces cochlioides* Drechs, are known to be the causal agents for the seedling diseases of sugar beets that growers commonly call "black root." General measures for control have been summarized by Coons and Kotila (*2*)[3]. The general root disease complex that starts in the seedling stage of the sugar beet plant and may persist throughout the life of the plant has been differentiated into two phases, first an acute phase in which the plants are killed as they grow out of the seed ball or within a week or two after emergence from the soil, and second a chronic phase affecting plants not damped off in which lateral rootlets and the terminal portion of the tap root are chiefly affected. *A. cochlioides*, although capable of causing damping off, is chiefly responsible for the chronic phase of black root—Kotila and Coons (*5*); Coons, Kotila, and Bockstahler (*3*).

Observations as made in Michigan, Ohio, Wisconsin, and Minnesota in 1941-1945 by these investigators had indicated that the sugar beet variety, U. S. 216, showed definite resistance to the chronic phase of black root and that a hybrid, S. P. 1-9-00, was highly susceptible. Supporting observations were made by Torrie, Downie, and Culbertson (*6*) on the same material. On the basis of these findings various inbred lines and their hybrids, as available from the leaf spot resistance project of the Division, were supplied for tests in 1944 at Holgate, Ohio (Kotila and Bockstahler), and at the South East Experiment Station of the Minnesota Agricultural Experiment Station, Waseca, Minn. (Culbertson). In these tests U. S. 216 and S. P. 1-9-00 were included as, respectively, resistant and susceptible checks. The extremely wet conditions in 1944 seriously influenced the stands in

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[2]Associate Geneticist and Assistant Pathologist, respectively, Division of Sugar Plant Investigations, Bureau of Plant Industry, Soils, and Agricultural Engineering. The writers wish to thank Dr. G. H. Coons, Principal Pathologist, Division of Sugar Plant Investigations, Bureau of Plant Industry, Soils, and Agricultural Engineering, U. S. Department of Agriculture, under whose direction these investigations were made, and Dr. H. K. Hayes, Chief, Division of Agronomy and Plant Genetics, and Dr. E. C. Stakman, Chief, Division of Plant Pathology and Agricultural Botany, Minnesota Agricultural Experiment Station, for helpful suggestions and criticisms during the course of these investigations and in the preparation of the manuscript.

[3]Italic numbers in parentheses refer to literature cited.

the field plantings at Holgate, Ohio, and it seemed clear that other pathogens as well as *A. cochlioides* were concerned in the death of the seedlings. Differentiation among the varieties for resistance to *A. cochlioides* was not clear-cut. Similarly, at Waseca, Minn., very rainy weather following the planting period brought about an almost complete loss of stands. However, from such plants as survived under the severe conditions, selections were made by Culbertson[4] and brought to seed under conditions permitting open pollination.

In 1945, plans were developed by the Division of Sugar Plant Investigations for repetition of the test of inbred lines and their hybrids at Waseca, Minn., on the field where the previous planting had failed. One important change was introduced in the test, namely, all seed was treated with a fungicide (Arasan) prior to planting since it had been concluded from the 1944 tests that the acute phase of the seedling diseases should be excluded so far as possible in order to limit the exposure to *A. cochlioides*.

Two series of investigations on the reaction of sugar beets to black root as caused by *A. cochlioides* were assigned in 1945 to the writers: (1) Field tests to determine the extent to which resistance already exists in sugar beet varieties and strains, and (2) greenhouse experiments to develop a methodology by which controlled exposures may be used in testing for resistance and susceptibility.

Materials and Methods

Field Experiments.—Tests were made at Waseca, Minn., of 216 open-pollinated seed progenies of mother beets that were selected by J. O. Culbertson in 1944 because they survived in heavily infested soil. These were compared with U. S. 216 and S. P. 1-9-00 in duplicate randomized 16-foot progeny rows in a field in which sugar beets had been eliminated completely by black root in 1944. As check varieties, U. S. 216, which had been reported to be resistant, and S. P. 1-9-00, which had appeared to be very susceptible, were planted in paired rows at 10-row intervals.

All seeds were treated with Arasan to protect against seed-borne pathogens and to reduce pre-emergence damping off. Data were taken on the percentage of post-emergence survival, relative vigor of top growth, and vigor of roots.

The mean survival percentage for each progeny was calculated after obtaining data on the initial and final stand of a measured, non-thinned section of each row. The mean percentage of survival for the two check varieties was determined in a similar manner, using data from the 62 paired check rows. The percentage data were trans-

[4]Dr. J. O. Culbertson transferred on February 15, 1945, to Division of Cereal Crops and Diseases. Breeding materials as obtained in his investigations were made available by him for this work.

formed to degrees by means of tables prepared by Bliss (*1*) and reprinted by Hayes and Immer (*4*).

Progeny rows were grouped into three classes on the basis of the average vigor of top growth in comparison with U. S. 216 in the two nearest check rows. The class designations were as follows: Class 1, growth exceeding that of U. S. 216; class 2, growth equalling; and class 3, growth inferior. These numerical ratings of the two rows of each progeny were averaged to obtain a mean top growth vigor index for each progeny.

A similar system of classification was used in comparing the vigor of the roots of each progeny row with that in the two nearest check rows of U. S. 216. These ratings were made only on the 59 progenies that exceeded U. S. 216 in vigor of top growth and in percentage of post-emergence survival.

Twelve inbred lines, 10 hybrids, 1 synthetic variety, and 1 commercial variety were compared at Waseca in an adjoining plot. These were tested also in soil that was only slightly infested with *A. cochlioides* at University Farm, St. Paul. These tests were made in eight randomized blocks in 33-foot single-row plots at Waseca and in 20-foot single-row plots at University Farm. Data were recorded on the yield of roots at Waseca and University Farm and on vigor of tops at Waseca only. In summarizing the root yield data in these trials at Waseca and University Farm, the inbred lines were classified as resistant or susceptible on the basis of their performance in these and previous unpublished studies.

In addition to the tests of progenies from selected roots and the tests of inbreds and their hybrids just described, 11 sugar beet varieties were grown in 4-row plots, 132 feet in length, on heavily infested soil in order that selections could be made from the most resistant sorts. U. S. 216 and S. P. 1-9-00 were planted at intervals throughout the field as check varieties. A mass-selected variety designated as 1942 Minnesota Synthetic No. 1 was included. This variety was developed by J. O. Culbertson in cooperation with the Minnesota Agricultural Experiment Station. It is the result of repeated mass selection of roots for high root yield and high sucrose percentage. The selections were made at Waseca, Minn., from varieties grown in leaf-spot-resistance evaluation tests and from plantings of genetic material. The plots were located on soils infested with *A. cochlioides*. Freedom from leaf spot and root rot was considered in making the selections.

Greenhouse Experiments.—Five strains of sugar beets that had been tested under extremely severe natural infestations in the field at Waseca were grown in the greenhouse in both naturally infested and artificially infested soils. The objectives of this experiment were

two-fold: (1) To develop methods of testing for resistance under controlled conditions and (2) to learn whether the reaction of strains under field conditions was similar to their reaction under greenhouse conditions in soils in which the only pathogen present was *A. cochlioides*.

Soil from the field trials at Waseca and a standard greenhouse mixture were used in these experiments. The five strains were grown in untreated naturally infested Waseca soil, in steamed Waseca soil, in steamed greenhouse soil, in steamed Waseca soil to which an inoculum consisting of a pure culture of *A. cochlioides* had been added, and in steamed greenhouse soil plus inoculum. The inoculum was grown in potato dextrose broth and after maceration was added uniformly to the soil.

Pertaining to their resistance to *A. cochlioides*, the five strains may be characterized as follows:

S. P. 1-9-00	Very susceptible to *A. cochlioides* under field conditions.
U. S. 216	Moderately resistant under field conditions.
Improved U. S. 215 x 216	U.S.D.A. variety resistant to leaf spot. It has about the same degree of resistance to *A. cochlioides* as U. S. 216, one of its parents.
Commercial No. 3	A locally adapted variety that showed resistance in 1945 field trials at Waseca.
Progeny No. 59	An open-pollinated progeny of a selected mother beet. The progeny was superior to U. S. 216 in percentage survival and vigor of roots in 1945 trials at Waseca under severe natural infestation with *A. cochlioides*.

Seeds were treated with Arasan and germinated in clean quartz sand. With the exception of Progeny No. 59 thirty healthy seedlings of each strain were transplanted in each plot of each soil treatment. Because of scarcity of seed some of the plots of Progeny No. 59 were limited to 15 seedlings. A split-plot type of experimental design was used. The soil treatments were the main plots and were replicated five times with the strains arranged at random in each soil treatment. Each main plot consisted of two greenhouse flats placed end to end. Data were collected on the average percentage survival of the seedlings of each strain and on the vigor of the seedlings in each soil treatment.

The percentage data were transformed according to Bliss's method before applying the analysis of variance. Each of the five soil treatments were analyzed as separate randomized block experiments.

Each seedling was given a vigor rating based on a series of 10 plants used as standards, ranging from dead to exceptionally vigorous. The percentage of the seedlings of each strain which fell in each vigor class in each soil treatment was determined.

Experimental Results

Field Experiments.—The mean post-emergence survival percentages for U. S. 216 and S.P. 1-9-00, as determined from the 62 paired check rows, were 21.8 and 8.7, respectively. According to the analysis of the transformed percentage data, these two varieties differ significantly in their rates of survival. Of the 216 progenies, 152 had a higher survival rate than U. S. 216. Three of them had lower survival percentages than S. P. 1-9-00.

When the progenies were compared with U. S. 216 in regard to vigor of top growth the following results were obtained:

Classification	Number of progenies
Superior to U. S. 216	70
Equal to U. S. 216	61
Inferior to U. S. 216	85
Total	216

Of the 70 that were superior in top growth, 11 were inferior in percentage of post-emergence survival and were not used in further studies. The roots of the 59 progenies with superior top growth and percentage of survival were lifted and compared with roots from the adjacent U. S. 216 check rows. On the basis of their average vigor in both replicates, the following results were obtained:

Classification	Number of progenies
Superior to U. S. 216	50
Equal to U. S. 216	6
Inferior to U. S. 216	3
Total	59

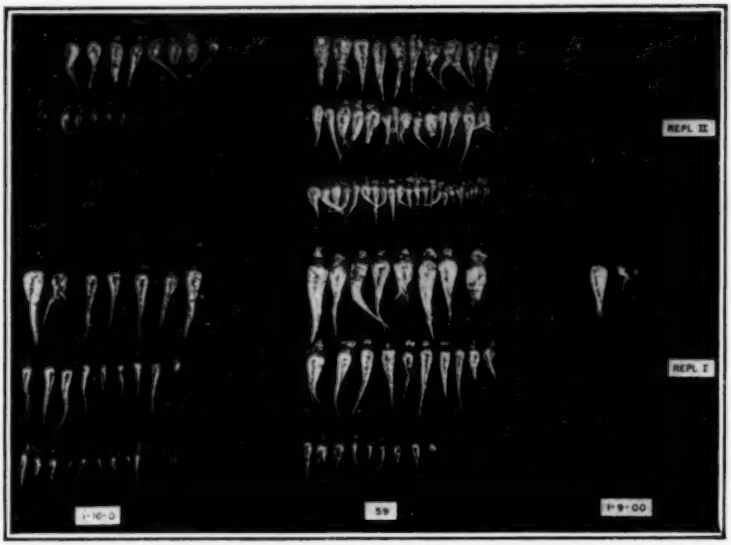

Figure 1.—Roots of three strains of sugar beets grown in non-thinned rows in soil with a heavy natural infestation of Aphanomyces cochlioides. Left to right: U. S. 216, Progeny No. 59, and S.P. 1-9-00.

There were striking differences in the vigor of the roots of the various progenies. Figure 1 shows the roots from Progeny No. 59, which was one of the superior progenies, in comparison with roots from adjacent rows of the two check varieties.

In the test of 24 inbred lines, hybrids, synthetics, and commercial varieties at Waseca in heavily infested soil some strains were almost completely eliminated, while others maintained good stands and produced quite vigorous roots despite the extremely adverse conditions. A fairly close relationship between the vigor of top growth and the yield of roots was also observed in this test. This relationship is of interest because it permitted the discarding of a high percentage of the seed progenies without resorting to lifting and examining roots. The data on the vigor of the top growth of the strains in comparison with U. S. 216 may be summarized as follows:

Classification	Number of strains
Superior to U. S. 216	2
Equal to U. S. 216	10
Inferior to U. S. 216	11
Total	23

One of the two strains that had mean vigor ratings which were significantly superior to that of U. S. 216 was unrelated to U. S. 216. S.P. 1-9-00 and U. S. 200 were among those with significantly poorer mean vigor ratings.

On the basis of their performance in 1945 at Waseca in heavily infested soil, at University Farm in lightly infested soil, or in previous studies, there were among these 24 strains 8 susceptible inbreds, 4 resistant inbreds, 4 crosses between susceptible inbreds, 5 crosses of susceptible x resistant inbreds, and 1 cross between resistant inbreds in addition to the commercial variety and the mass-selected synthetic variety designated as Minnesota Synthetic No. 1. The root yields of the 24 strains, summarized according to this classification, are presented in table 1.

Table 1.—Summary of root yield data from tests of 24 sugar beet strains on heavily infested soils at Waseca, Minn., and on lightly infested soils at University Farm, St. Paul, Minn., in 1945.

Type of material	Number of strains in each group	Root yield in tons per acre			
		Waseca		University Farm	
		Range	Mean	Range	Mean
Susceptible inbreds	8	0.4-2.3	1.4	6.7- 9.7	8.5
Resistant inbreds	4	3.0-5.0	4.1	8.1-12.1	10.5
Susceptible x susceptible inbreds	4	1.2-3.9	2.2	9.6-10.5	10.1
Susceptible x resistant inbreds	5	2.6-5.9	3.9	10.9-12.9	12.0
Resistant x resistant inbreds	1	---- - ----	5.5	------ - ------	12.3
Mass selected synthetic variety	1	---- - ----	4.8	------ - ------	13.1
Commercial locally adapted variety	1	---- - ----	4.2	------ - ------	12.1

Analysis of variance of the data from the tests at Waseca and University Farm showed that in both experiments varietal differences exceeding that required for statistical significance at the 1 percent level of significance were present. It is apparent that the yield of the resistant inbreds is significantly greater than that of the susceptible inbreds and that certain of the hybrids were considerably superior to others.

Figure 2 shows a four-row plot of Minnesota Synthetic No. 1 in comparison with a commercial variety and S.P. 1-9-00. Tests of this mass-selected variety and of seed progenies of selections from it indicate that it contains a relatively high percentage of individuals with resistance equal to or higher than that of U. S. 216. Two synthetic varieties that included among other components selections from leaf-spot-resistant strains obtained from Italy had many plants in the four-row plots that appeared to be more resistant than U. S. 216. Hybrids between U. S. 216 and miscellaneous inbreds exhibited a degree of resistance equal to that of U. S. 216. S.P. 1-9-00 was very susceptible in this experimental planting.

Figure 2.—Comparative effect of black root on stand and top growth of three varieties of sugar beets. Left to right: Commercial No. 1, Minnesota Synthetic No. 1, and S. P. 1-9-00.

Greenhouse Experiments.—The average percentage survival of the five strains in each of the five soil treatments as contrasted with the average percentage survival of three of the strains in the field at Waseca are tabulated in table 2.

The tests in the naturally and artificially infested Waseca soils and the artificially infested greenhouse soil showed statistically significant differences in the percentage of survival of the strains although the two steam-sterilized soils gave no significant differences.

S.P. 1-9-00 was considerably inferior to the other four strains in both of the artificially infested soils and was significantly lower than

Table 2.—Average percentage survival of seedlings of five sugar beet strains grown in the greenhouse and of three strains grown in the field.

Strain No.	Percentage survival of seedlings					
	Test in field at Waseca, Minn.	Test conducted in greenhouse				
		Waseca soil			Greenhouse soil	
		Untreated	Steamed	Steamed plus inoculum	Steamed	Steamed plus inoculum
S. P. No. 1-9-00	9	71	83	11	83	39
U. S. 216	22	75	81	35	75	61
Imp. 215 x 216	....	72	81	28	80	66
Commercial	....	79	90	18	89	53
Progeny No. 59	52	89	87	29	72	57

Progeny No. 59 in the naturally infested soil in the field and in the greenhouse. It is of some interest that the commercial variety was, in general, somewhat inferior to Progeny No. 59, U. S. 216, and Improved U. S. 215 x 216. This was most noticeable in the two soils that were steam-sterilized before adding inoculum.

Seedlings of Progeny No. 59 had the highest average vigor index in the naturally and artificially infested Waseca soils and had the highest percentage of seedlings with above-average vigor in all three soils in which *A. cochlioides* was present. Seedlings of U. S. 216 and Improved U. S. 215 x 216 in the infested soils consistently had a higher average vigor index than seedlings of S.P. 1-9-00, which was of equal or higher vigor in the steam-sterilized soils and of lowest vigor in the infested soils.

Summary

Aphanomyces cochlioides, one of the pathogens responsible for black root of sugar beets, causes serious yield reductions and abandonment of large acreages of sugar beets in the North Central States.

Field and greenhouse experiments made in 1945 in Minnesota show that the sugar beet varieties U. S. 216 and S.P. 1-9-00 differ significantly in their resistance to *A. cochlioides*.

A number of inbred lines of sugar beets and crosses between them were studied in replicated field experiments in heavily infested soils and in lightly infested soils. In general when one or both of the parent inbreds were resistant the hybrids significantly outyielded hybrids between two susceptible inbreds.

In preliminary greenhouse experiments the reaction to *A. cochlioides* of three sugar beet strains corresponded closely to the field determinations for these strains.

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Inbred Lines From Curly-Top-Resistant Varieties of Sugar Beets[1]

F. V. Owen, Albert M. Murphy, and George K. Ryser[2]

All the curly-top-resistant varieties of sugar beets developed by the United States Department of Agriculture and now in commercial use were derived by the relatively simple method of mass selection. In these commercial varieties plant populations are heterogeneous and practically all the individual beets are so strongly self-sterile that their sexual reproduction depends largely upon fertilization with pollen from other beets in the population.

The limitations of mass selection methods were realized, so an early search was made for exceptional self-fertile, curly top resistant biotypes that could be propagated by selfing (*6*)[3]. Interest in the self-fertile lines was soon intensified by the discovery of male-sterile types which greatly facilitated plans for hybridization work. The male-sterility was found to be produced by maternal or cytoplasmic inheritance. Because of this non-Mendelian type of inheritance, it is possible to make combinations of parentage to produce populations, all plants of which are completely male-sterile. The details of the inheritance of male-sterility and methods of producing male-sterile populations have been discussed in a recent paper (*7*). A similar type of male-sterility with similar possibilities for facilitating hybridization has been found in onions (*4*).

Origin and Description of the Self-Fertile Lines

Self-fertility was first detected in strain 286 (*1*) which in 1930 was more highly resistant to curly top than any other strain tested. Strain 286 was so low in sugar, however, that it was withheld from the list of strains combined to form the original commercial variety U. S. 1 (*2*) from which most of the subsequent curly-top-resistant varieties have been developed. Self-fertilized seed from a single beet from strain 286 was designated S. L. 1167. Beets grown from S. L. 1167 seed and from S_2 and S_3 progenies were extremely uniform and always produced badly sprangled roots (figure 1).

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[1]Cooperative investigations with the Curly Top Resistance Breeding Committee, an organization representing all the sugar companies operating in curly top areas.

[2]Senior Geneticist, Assistant Pathologist, and Collaborator, respectively, Division of Sugar Plant Investigations, Bureau of Plant Industry, Soils, and Agricultural Engineering, Agricultural Research Administration, U. S. Department of Agriculture.

[3]Italic numbers in parentheses refer to literature cited.

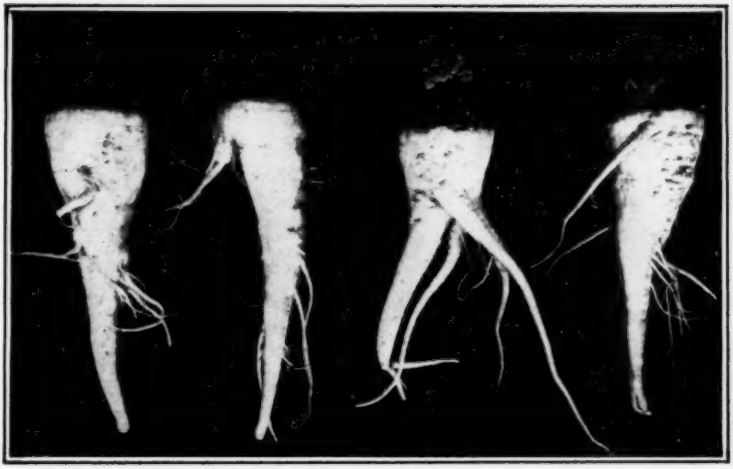
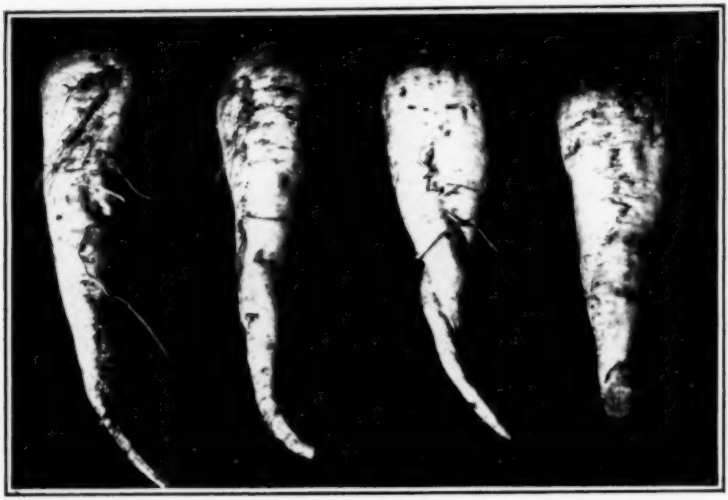


Figure 1.—Typical beets of original self-fertile line S.L. 1167, showing undesirable sprangled root habit. S.L. 1167 carried a Mendelian factor for self-fertility which made inbreeding work possible. Through hybridization this Mendelian factor has been transferred to a wide variety of curly top resistant sugar beets, and all beets carrying the factor are highly self-fertile.

Hybrids with S. L. 1167 were disapointing, but after a series of outcrosses and backcrosses to the self-sterile commercial varieties some fairly acceptable inbred lines were eventually produced. Primary attention was given to the degree of curly-top resistance and all lines except those possessing the very highest degree of resistance were rapidly eliminated. The best line available in 1943 was designated CT9. The designation "CT" is intended to imply outstanding curly-top resistance. The roots of CT9 beets in the S_1 generation were considered too long (figure 2A), but selection in the second generation brought about considerable improvement (figure 2B).

Genetic studies (*6*) showed that the self-fertility of the inbred line S. L. 1167 was determined by a single Mendelian factor whose inheritance is governed by the rules of the oppositional hypothesis. By making tests with inflorescences placed under paper bags, self-fertility was recovered in outcrosses and backcrosses to the self-sterile commercial varieties. The CT9 beets were just as highly self-fertile as beets of the original S. L. 1167 line produced 12 years earlier.

The degree of self-fertility in these inbred lines of sugar beets is rather extreme. Even in open pollinations where these beets were surrounded by a mass of foreign pollen, the offspring were frequently



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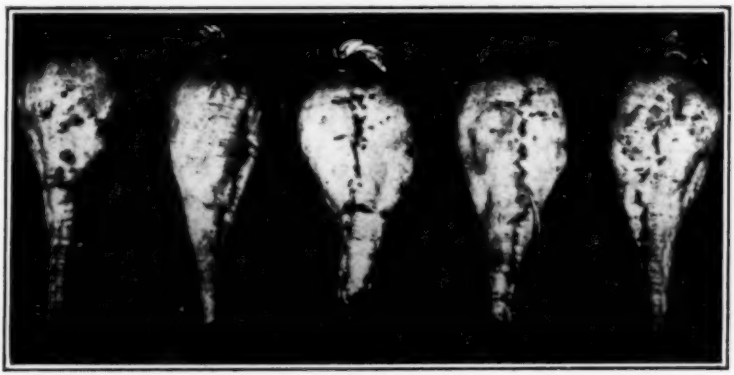

B

Figure 2.—Beets of inbred line CT9. A.—S_1 generation. B.—S_8 generation beets after selecting for shorter and more desirable root type.

sufficiently uniform to indicate complete selfing of the maternal parent. A test in 1944 consisting of 40 *rr* self-fertile beets, open pollinated and surrounded by *Rr* and *RR* beets, showed that 16 of the 40 beets had been completely self-fertilized. Ten additional beets showed less than 5 percent crossing and the maximum amount of crossing observed on any one beet was 14.4 percent.

With this very high degree of self-fertility it would be futile to expect sufficient natural hybridization between the inbred lines in seed fields to insure the production of hybrid seed. The use of male-sterility is the only method of obtaining hybrids between the inbred lines which appears practical.

Male-Sterile From U. S. 22 x CT9

In 1944 the male-sterile strain S.L. 1-121, considered equivalent to the variety U.S. 22, was crossed with S_1 beets of the line CT9. Hybridization was accomplished in a garden isolation by using the male-sterile strain S.L. 1-121 for the female parent and the self-fertile line CT9 for the pollen parent. The hybrid population was labelled S.L. 4108.

In 1945 at Jerome, Idaho, S.L. 4108 was included with a large number of varieties grown for observation under severe curly-top exposures produced by making midsummer plantings adjacent to early planted beets in a curly top environment (5). In observation rows S.L. 4108 showed a high degree of curly-top resistance and the variety was equal in this respect to U.S. 22/3, the third release of U.S. 22 and the most highly resistant commercial variety yet produced.

Results obtained with the hybrid S.L. 4108 in 1945 at Salt Lake City under curly-top-free conditions are shown in table 1. A gain of over 11 percent in yield of sugar per acre is indicated for S.L. 4108 as compared with U.S. 22/3, and a gain of 13.5 percent as compared with the U.S. 33 variety. Five additional mass-selected varieties were included in the test with yields of sugar per acre not significantly different from those of U.S. 22/3 and U.S. 33. S.L. 4108 produced 12 percent more sugar per acre than the average of the seven mass-selected varieties.

Table 1.—Yield comparisons with the male-sterile hybrid S.L. 4108*.

Variety and population number	Acre yield			
	Available sugar Tons	Beets Tons	Sucrose Percent	Purity Percent
S.L. 4108	4.635	34.16	15.52	87.19
U.S. 22/3 (S.L. 32)	4.162	32.11	15.12	85.87
U.S. 33 (S.L. 333)	4.078	29.68	15.83	86.65
Difference for significance, 19:1 odds	0.205	1.11	0.35	0.81

*Test conducted near Salt Lake City, Utah, on Taylorsville loam soil type with 24 replicated plots for each of 10 varieties in the test. Single plots consisted of 4 rows 20 inches apart, 60 feet long, with yields based on weights taken from the two center rows. Two 10-beet samples were taken from each plot for sucrose and purity determinations. Purity refers to percentage of sugar on total solids. Available sugar per acre refers to: tons beets x percent sucrose x percent purity.

Approximately one-third of the increased yield from S.L. 4108 may be accounted for by superior resistance to a petiole- and crown-rot disease produced by an unknown organism which occurred in the field where the test was conducted. The other varieties suffered a loss of 1 to 3 percent of beets killed by the disease.

Susceptible Variety x CT9

The leaf-spot-resistant variety U.S. 216 (*3*), which is very susceptible to curly top, was crossed with S_2 beets of CT9. This hybrid was compared with other varieties under a severe curly-top exposure at Jerome, Idaho, in 1945. The disease resistance of the U.S. 216 hybrid was surprisingly high (table 2). In a June 19 planting where the disease was severe enough to completely eliminate susceptible beets, the U.S. 216 hybrid compared fairly well with the variety U.S. 22/3 but was inferior to the hybrid U.S. 22/3 x CT9. In the extremely severe curly-top exposure in the July 5 planting, the injury to the U.S. 216 hybrid was more severe but disease exposures of this intensity are not commonly encountered under natural conditions. In many curly-top areas it is probable that this U.S. 216 hybrid would have ample curly-top resistance for commercial utilization.

Table 2.—Yield data from summer plantings at Jerome, Idaho, in 1945 under severe curly top exposures.

Variety		Tons beets per acre*	
S.L. number	Description	June 19 planting	July 5 planting
5409	U.S. 22/3 x CT9	11.29	4.28
32	U.S. 22/3	9.33	2.32
5410	U.S. 216 x CT9	8.91	1.07
1-300	Susceptible variety†	0.0	0.0

*Yields were taken from single two-row plots 50 feet in length.

†The susceptible variety was the popular German variety R. & G. Old Type or Kleinwanzleben E.

Number of Germs Per Seed Ball

A search for lines with strictly single-germ or monolocular seed balls has not yet been successful, but nevertheless there have been striking differences in degree of the multilocular condition. Observations made in 1944 among individual self-fertile beets obtained from various sources showed wide variation. In table 3 the extremely multiple condition is represented by S.L. 4704 where 90 percent of the seed balls had three or more locules. S.L. 4608 represents a decided contrast, with only 6 percent of the seed balls showing three or more locules, the remaining 94 percent of the seed balls being bilocular or unilocular. The inbred line S.L. 3555 was exceptionally

bilocular. From this line 26 beets were examined during seed production. There was some variation, so the seed from five selected beets of S.L. 3555 was composited under the number S.L. 4233 (table 3) and the seed from the remaining 21 beets was composited under S.L. 4235. A high proportion of bilocular seed balls was observed in both populations with 93 percent for population S.L. 4233 and 82 percent for population S.L. 4235.

The viable germs per seed ball were observed to be considerably less than the total number of locules. For example, in population S.L. 4608 with a preponderance of bilocular seed balls (table 3) a count of seedlings grown in greenhouse soil showed that 66 percent of the seed balls produced only one viable seedling per seed ball. This high percentage of single seedlings per seed ball from a bilocular inbred line approaches the percentage of single obtained from some comercial lots of segmented seed.

Table 3.—Number of locules or potential germs per seed ball, with locule counts based on observations of 400 seed balls from each population.

Population or S.L. number	Classification of seed balls						
	1 locule	2 locules	3 locules	4 locules	5 locules	6 locules	7 locules
	Percent	Percent	Percent	Percent	Percent	Percent	Percent
4704	0.0	10.0	41.2	41.9	5.0	1.8	0.2
4608	4.7	89.2	5.7	0.3	0.0	0.0	0.0
4233	1.7	93.0	4.0	1.3	0.0	0.0	0.0
4235	2.0	82.0	12.2	3.5	0.3	0.0	0.0

Discussion and Conclusions

Much has been achieved by mass selection in the development of curly-top-resistant varieties of sugar beets, but the limitations of the method are so great that the development of improved breeding methods has become imperative. The 12 percent advantage, obtained from the hybrid with the inbred line CT9, over present commercial varieties is encouraging. Only 1 year's results are available, but it is confidently expected that still better hybrids can be produced. Besides the increased vigor from the use of the hybrids with the inbred lines, much greater uniformity is possible, and this should be of major importance in the mechanization of harvest operations.

Not only has it been more feasible to obtain resistance to a major disease like curly top through the use of inbreds, but it has also been more feasible to obtain resistance to minor or more localized diseases. An example of adaptation to a localized situation is the resistance of the CT9 hybrid to a petiole- and crown-rot disease at Salt Lake City. In the same way, greater resistance to bolting is being obtained

through the use of the curly-top resistant inbred lines. Results also indicate that lines with bilocular seed balls can be developed which may eventually make artificial shearing or segmenting of seed unnecessary.

The very high degree of curly top resistance now available in the S_3 generation of line CT9 makes it possible to consider utilization of CT9, or its male-sterile equivalent, in hybrids with varieties not resistant to curly top, if in such hybrids increased vigor or increased sugar content can be obtained.

Sprague (8) states that with conventional corn breeding methods through development of inbreds, a minimum of 10 to 12 years is required for the completion of experimental testing and the release for commercial production of the best hybrids. This consideration of time requirement emphasizes the importance of doing everything possible to hasten the development of superior inbred lines of sugar beets and of devising the most effective procedures of evaluating them in hybrid combinations.

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Results In 1945 From Hand-Singled and Hand-Blocked Sugar Beets as Grown From Sheared Seed

S. B. NUCKOLS[1]

Hand thinning of sugar beets to leave single plants approximately 12 inches from the neighboring plants in the row is the common practice of almost all sugar beet growers in the United States. Hand singling of the sugar beets has been thought necessary in order to obtain maximum yields. This operation is known as one of the most expensive, time-consuming, and tedious operations connected with the growing of sugar beets. Under present conditions, when labor is difficult to obtain, it has become advisable to conduct some tests to assess the value of this universal practice in relation to alternative practices requiring less labor.

In 1924 the author of this paper began a series of experiments to find if two beets at a place in the row (commonly called doubles) produce as great a yield as is produced when only single beet is left for each 12-inch space. These experiments were continued for 7 years and the results indicated that there was no significant difference between the yields of one beet or two beets in a hill. No formal publication of these tests was made but the information was widely discussed at some of the meetings of sugar beet agriculturists and growers. When two beets were grown as doubles, approximately half of the hills had one beet of normal size and the other beet was too small for commercial use. When there were two beets of commercial size in a place, each root was smaller than normal and often the two roots were twisted around each other. Because of the greater number of roots produced per acre the yields of commercial sized beets were maintained if doubles were left at thinning time. In these same tests, three and four beets per hill were left in some plots and very small beets were produced in many of the hills. It was found that leaving more than two beets in a space reduced the acre yield of commercial roots. The author of this paper was not considering the mechanization of sugar beet thinning when conducting these earlier experiments but later investigators have had mechanization of thinning in mind when conducting experiments in which one, two, three, four or more beets were left in a hill (*1, 2*).[2] Some of these

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[2]Italic numbers in parentheses refer to literature cited.

tests have been conducted by hand blocking and some with mechanical blocking. In general the results in other areas from hand or mechanical blocking with omission of hand singling have not shown serious effects upon the acre yields of commercial roots. There is a need for studies of this character in a number of locations over a series of years to establish a safe practice.

In 1945 at Torrington, Wyo., in cooperation with the Goshen County Experiment Station of the Wyoming Agricultural Experiment Station, a field was planted with sheared sugar beet seed. A replicated series of plots was set up to determine the effects on yield if hand singling was omitted. It was sought to determine the effects on yield because the saving in labor from omission of hand singling would in part counterbalance any reduction in gross returns per acre. In these tests all plots were blocked by means of 7-inch, long-handled hoes. Later one-half of each of the plots (split-plot design) were hand singled. Each main plot was 16 rows of beets wide and 50 feet long. There were 10 replicates of each treatment. The field selected was a sandy loam and had received a heavy application of manure before plowing. Sheared sugar beet seed was planted at the rate of 3½ pounds per acre on March 26 but no plants emerged until April 25. Blocking was done May 30 when the plants had four to six leaves. The hand singling of beets was done June 1.

Ten days after thinning the plots were all cultivated by the use of a bean weeder to remove small grass and weeds. This use of the bean weeder did not injure the small sugar beets but destroyed many of the small weeds and grass and greatly reduced the labor normally required for hand labor of hoeing sugar beets. Hand hoeing is usually considered a greater task on blocked sugar beets than on singled sugar beets. This use of the bean weeder is a relatively new and not common practice in the weeding of sugar beets and is perhaps one of the important factors in the outcome of this test.

An attempt was made to space the beets in this test 12 inches apart, and at harvest there was an average of 78 hills per 100 feet of row of the hand-singled plots. Where the plots were blocked there was an average of 89 hills and 106 beets per 100 feet of row. This indicated that some of the hills were destroyed during the operation of hand singling. At harvest 4 percent of the hills where the beets were blocked had three or more beets per hill, 27 percent had two beets per hill, and 69 percent had only one beet. This distribution of beets among the hills leaves 96 percent of the blocked hills such that a normal yield can be expected and the 4 percent of hills with three or more beets per hill; this 4 percent should have been

chopped at the first hoeing either to reduce the stand or eliminate all beets in the hill.

All the hills containing two or more beets were harvested separately from the single beets and weighed separately. The single beets produced an average of 1.78 pounds of commercial roots from each hill, while the hills consisting of more than one beet produced an average of 1.68 pounds of commercial roots per hill. There was an average loss of 5.1 percent in weight of commercial roots where more than one beet was left per hill and there were 1.56 beets produced per hill where more than one beet was left. Since there was a loss of stand by the process of hand singling there was a compensation for the lesser yields from the hills where more than one beet was left. The mean yield per acre from the blocked beets was 16.11 tons per acre. From the hand-singled plots 15.76 tons of roots per acre were produced. The difference in tons of roots per acre is not significant nor was there any significant difference between sucrose content of roots or gross sugar per acre produced from the two types of sugar-beet plots (table 1).

Table 1.—Comparison of stands, acre-yields of roots, sucrose percentages, and gross sugar production on sugar-beet plots in which the plants were (1) hand-singled and (2) blocked but not hand-singled. Torrington, Wyo., 1945. (Data given as 10-plot averages.)

Treatment	Stand[1] at harvest	Acre-yield of roots	Sucrose	Acre-yield of gross sugar
	Percent	Tons	Percent	Tons
Blocked and hand singled	78	15.76	17.11	2.708
Blocked but not hand singled	89	16.11	17.58	2.842
Difference required for significance, odds 19:1	8.77	1.01	.64	.433

[1]Number of hills per 100 feet of row.

The results obtained from this single experiment cannot be taken as indicating that similar results necessarily will be obtained from subsequent tests of this type. Too much depends upon the stand of beets that is obtained from planting sheared seed. When the quantity of sheared seed planted per acre is kept small in order to obtain an initial stand that can be easily blocked by the use of a long-handled hoe so as to leave prevailing, a single beet in a place, there are certain to be stands so sparse that replanting will be necessary. On the other hand some stands may be too thick for good results from blocking only. In other fields weed control may be so great a factor at hoeing time that little labor is saved over the conventional blocking and singling. In this particular instance an acceptable stand was obtained and weed control was good.

The evidence is insufficient for positive recommendations for

general practice. The tests are to be continued on a larger scale and more widely distributed in the sugar beet districts of the Northern Great Plains area. However, these results, taken in conjunction with reports from similar tests conducted elsewhere, do indicate definite promise that if initial stands are suitable, and if proper steps for weed control are taken, hand singling may in many cases be omitted without loss in yield of commercial beet roots per acre.

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Insects As a Minor Factor in Cross Pollination of Sugar Beets

DEWEY STEWART[1]

It is a common observation that numerous insects visit flowering sugar beets. The relative importance of insects and wind as agents of cross-pollination of sugar beets has not been determined. Tests were conducted in 1938 and 1940 at Arlington Farm, Va., to evaluate these two agencies of pollen transport.

Sugar beet plants were enclosed in 30-mesh wire cloth cages except for one or more flowering branches per plant that were left outside. The branches outside the cages were exposed to visitation of insects, whereas the plant inside was protected from large insects. It is thought that the screen wire offered little impediment to wind-borne pollen so that the portions of the plant inside a cage and the branches outside had equal exposures to wind-borne pollen. The plants were grown each year in a seed field approximately one-third acre in size. The relative percentages of cross pollinations for the two types of exposure were determined by means of the inheritance of the factors conditioning anthocyanin color. The general population of plants in the seed field were pink-hypocotyl type (R-) except for a small percentage of plants that were homozygous recessive. Green-hypocotyl plants or the recessive phenotype were caged. The pink-hypocotyl seedlings in the progenies of these caged plants were identified crosses.

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Results of a test with the sugar beet variety U. S. 215 are given in table 1. The mean percentage of identified cross pollinations within the cages was not significantly different from the mean percentage obtained from the branches outside.

Table 1.—Comparison of cross pollinations' occurring in caged (30-mesh screen) and uncaged parts of U. S. 215 plants. Arlington Farm, Va., 1938.

Location of plant		Total seedlings grown from seed produced		Pink hypocotyl seedlings grown from seed produced	
		Inside of cage Number	Outside of cage Number	Inside of cage Percent	Outside of cage Percent
Within seed field	1	308	444	70.8	68.0
Within seed field	2	88	322	68.2	61.2
Within seed field	3	531	472	65.4	66.1
Within seed field	4	208	456	64.9	59.2
Mean†		.....	.....	67.325	63.625
270 feet from field	5	51	57	58.8	68.4
850 feet from field	6	81	10	11.1	30.0

*Identified by the R factor. Mother plants rr. Pollen source not of one genotype but prevailingly R pollen was produced in the field.

†Mean difference of 3.7 percent not statistically significant by t-test.

Two sugar beet plants known to be of the rr genotype were placed in a meadow adjacent to the sugar beet seed field, one plant being placed 270 feet and the other 850 feet distant. It is interesting to note that the percentages of identified cross pollinations that occurred on the plant 270 feet from the seed field, irrespective of whether the branches were caged or not, did not differ strikingly from the cross pollination percentages obtained for plants located in the seed field. For this distance the wind apparently dispersed the pollen in a relatively effective amount.

The plant 850 feet from the seed field gave a marked reduction in cross pollination percentages. Seed production on the plant was largely from selfing.

Results of 1940 are given in table 2. The results were obtained with green-hypocotyl plants of U. S. 22 grown in a seed field in which the plants were essentially a pure stand of F_1 of U. S. 216 x U. S. 22 and other curly top resistant varieties. The F_1 plants were heterozygous (Rr) with respect to the genes conditioning hypocotyl color. The caged plants were the recessive genotype, and the seedling progenies grown from them should give an approach to a 1:1 ratio for hypocotyl color provided the plants caged were not self-fertile. The respective percentages of pink-hypocotyl seedlings, 44.2 percent and 45.3 percent for inside and outside the cages indicate that a high de-

Table 2.—Comparison of cross pollinations* occurring in caged (30-mesh screen) and uncaged parts of U. S. 22 plants. Arlington Farm, Va., 1940. (Values given as means of 8 plants grown within seed field.)

	Seed produced		
	Inside of cage	Outside of cage	Mean Diff.
Total seedlings	207.4	151.5	
Seedlings per seed ball	1.586	1.528	.058†
Percentage germination	70.4	46.9	23.5‡
Percentage pink-hypocotyl seedlings	44.2	45.3	1.1†

*Identified by the R factor. Mother plants rr. Pollen source prevailingly Rr plants (F_1's U. S. 216 x U. S. 22 and other curly-top resistant varieties).

†Not statistically significant by t-test.

‡Statistically significant. Odds greater than 99:1.

gree of cross pollination occurred. The mean percentage of the identified cross pollinations inside the cages was not significantly different from the mean percentage for the outside branches. The number of seedlings per viable seed ball indicates similar quality of seed was produced under the two exposures. The germination percentage is much lower for the seed produced on the outside branches that were exposed to the feeding of larger insects.

These experiments indicate that wind is an effective agent of cross pollination for sugar beets and it alone is sufficient to bring about the necessary transfer of pollen between plants within a seed field to assure seed production and a high degree of hybridity. Although larger insects may contribute to the total pollen exchanged between flowering sugar beets, they do not appear from these tests to be an essential agent of pollination and seed production. The role in cross pollination of sugar beets of thrips and other small insects not excluded by 30-mesh screen wire was not evaluated in these tests.

Single-Germ Seed

H. E. Brewbaker, R. R. Wood, and H. L. Bush[1]

A single-germ seedball is of obvious and immediate interest to the sugar beet industry. Mechanization of the thinning operation demands small, uniform-sized seed units, this demand having resulted in the mechanical cracking or segmenting operation. While this has greatly aided the mechanization program, it is a costly operation. The recovery of commercial segmented seed based on the original is low and there is a considerable percentage of seed units with damaged germs which are irrecoverable by any seed cleaning or screening process, the true germination of the seed being thereby proportionately reduced.

Single-germ seed units are not uncommon since there is a very great variation on most normal plants from one to many germs. Plants having a high degree of single-germness are so scarce, however, that they are almost non-existent. Perhaps this is not surprising since the single-germ seed are rather flat and as a result do not roll off the drape which has been universally used for cleaning seed from broken leaves and sticks. As a result, they have been consistently discarded with the trash. Any inherited character would tend to disappear under these conditions.

An extensive attempt made as early as 1903 by the U. S. Department of Agriculture to develop a strain of sugar beets characterized by single-germ seedballs was unsuccessful.

A most encouraging report of progress in this connection was made by M. G. Bordonos (*1*)[2] who reported the single-germ character to be "recessive" in nature and the F_1 generation to have "multilocular seedballs with a varying number of single-germ seeds among them." In F_2 he found "the number of segregated unilocular forms varies from 20 to 30 percent." He stated further that this figure included unilocular types which did not bloom the first year. Bordonos described the "unilocular" or single-germ plants as being "characterized by vigorous vegetative development and a peculiar type of seed bush," the latest maturing forms being "trotzers." Table 1 is taken from his paper:

The discovery of one plant having a high percentage of single-germ seedballs in some of the breeding material at Billings, Mont., by R. R. Wood in 1944 revived hopes for the existence of an hereditary single-germ character in the Great Western seed stocks. This plant (4436-13) was quite normal in appearance and time of maturity

[1]Director, Agronomist, and Statistician-Agronomist, respectively, Experiment Station, Great Western Sugar Company, Longmont, Colo.

[2]Italic numbers in parentheses refer to literature cited.

Table 1.—Segregation of F_2 hybrids of single-germ beets by number of flowers and dates of flowering (Bordonos).

Dates of Flowering	Number of flowers per seedball (average)													
	0	1.0	1.25	1.50	1.75	2.00	2.25	2.50	2.75	3.00	3.25	3.50	3.75	Tot.
May 15-30	–													
June 1-15	–							1						1
June 15-30	–	11	4	13	101	331	65	64	28	22	2	4	4	649
July 1-15	–	89	1	1	41	150	30	21	3	11	–	2	–	349
July 15-30	–	40	–	–	1	2	2	1	1	–	2	–	–	58
Aug. 1-15	–	17				1								18
Aug. 15-30		1												1
Sterile	100													100
"Trotzers"	39													39

except that the seedballs were 70 percent single, 29.9 percent double, and 0.1 percent triple in germ or locule units. It occurred in an open-pollinated breeding group, the seed in all probability having resulted from pollination with many (164 roots in group) apparently normal plants. Single-germ seed units from this plant were planted in the greenhouse under artificial lights in December 1944. The F_1 plants, which were allowed to sib-pollinate, had mostly double-flower clusters[3] and consequently double-germ seedballs. The seed was harvested in time to plant to the field in April 1945. An unselected lot of 405 F_2 roots was planted in the greenhouse November 9, 1945. Some 386 of these F_2 individuals reached the early inflorescence stage, at which time they were indexed for flower-cluster condition, the data[4] for which are presented by dates of indexing in table 2.

While there are some vegetative types of plants in the population, the two single-flowered plants are quite normal in appearance and there does not appear to be any correlation of the vegetative condition with the number of flowers in the cluster, such as was reported by Bordonos. It appears doubtful from this segregation if the single-germ character can possibly be a simple recessive in inheritance; there would, however, seem to be little doubt that it is hereditary in nature.

Further encouragement regarding the hereditary basis for the single-germ character was occasioned by the discovery in 1945 at Longmont, Colo., of one inbred line (selfed one generation) with four

[3]After this report was written another population came into seedstalk in the Longmont greenhouse under apparently more favorable growing conditions, the plants being very vigorous, and there appears to be a greater tendency for multiple-germness than was evident on the plants grown in the same house the previous winter.

[4]The data included in this table were completed after the original report was prepared and delivered to the Society meetings.

Table 2.

Date 1946	Singles*	Doubles**	Triples (Percentage)				Quadruples (Percentage)			Tot.
			25	50	75	100	25	50	75	
1-25	1	53	3	12	25	22	1	2	2	121
2- 1	1	41	2	11	14	5	2	0	0	76
2- 5	0	27	3	4	10	6	4	2	0	56
2-11	0	34	0	5	6	8	2	1	1	57
2-16	0	11	2	3	0	0	0	1	1	18
2-21	0	5	3	2	2	3	1	1	0	17
2-27	0	12	1	3	3	4	0	1	0	24
3- 6	0	7	4	2	1	2	1	0	0	17
Total	2	190	18	42	61	50	11	8	4	386

*Estimated at not less than 75 percent single-flowered.
**Estimated at not less than 90 percent of double-flowered clusters on any plant so indexed.

plants, each of which matured single-, double- and triple-seed units as follows:

Root No.	Percentage singles	Percentage doubles	Percentage triples
4538-489	87.2	12.4	0.4
-487	63.1	36.9	0
-490	18.0	80.4	1.4
-488	7.0	86.2	6.8

These four plants were quite normal in appearance and they seem to provide excellent material for a study of both the single-germ and double-germ characters.

The highly double-germ condition of the F_1 generation (see footnote 4) from plant No. 4436-13 and also the double-germ sister plants 4538-490 and 4538-488 indicated the possibility of this condition being associated with segregation for single-germness. In a careful study of some 5,180 growing plants at Longmont and 7,940 plants at Billings in 1945, just 3 at Longmont and 4 at Billings were found which matured only single- and double-germ seedballs. The seed from these plants varied from 8.0 percent to 30.8 percent singles and from 69.2 percent to 92.0 percent doubles. An additional 18 plants were recorded in the field at Longmont out of 5,180 studied as "mostly doubles," the seed on these varying from 2.6 percent to 23.8 percent singles, 75.8 percent to 94.8 percent doubles, and 0.2 percent to 3.2 percent triples.

The purpose of this paper is to report what appears to be some significant progress toward the isolation of an hereditary single-germ character. The five single-germ plants so far obtained vary

some toward double-germ units; perhaps as much as 15 to 30 percent double-germness may be expected. The results would suggest the possibility of the single-germ character being a recessive with perhaps three genes being involved, and the double-germ condition being an intermediate in the segregation for single- and multiple-germ characters. Such hypotheses at this time are intended only to be of some possible assistance in further searches for the single-germ character in the sugar beet.

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Seed Size in Relation to Development and Yield of Sugar Beets

CHARLES PRICE and EUBANKS CARSNER[1]

Size of seed was one of the early standards used in the sugar beet seed trade in Germany and other European countries. Large seed balls were recognized as giving a higher percentage of germination than seed balls of medium and small size. The minimum size or diameter of seed balls acceptable was 2.5 millimeters. The German seed standards served as a guide in the early sugar beet seed contracts in this country when commercial seed growing was started 12 years ago. Later, interest in seed size arose among the directors of the West Coast Beet Seed Company and in 1938 the senior author was requested to supply sized seed for experimental purposes. Seed of the variety U.S. 12 grown at Hemet, Calif., was separated into four sizes by using screens of 4, 3.5, 3, and 2 mm. diameters. Seed of each of the four sizes was shipped to six sugar companies for experimental purposes. One of the field tests, conducted near Salinas, Calif., by the Spreckels Sugar Company, was observed several times during the season. It was noted first that in the plots planted with the smallest seed the seedlings were slower in emerging than those in the plots planted with the larger seed. Later, it was noted that the plots planted with large seed had thick stands and those planted with small seed had very poor stands. Interest in the question of seed size lagged after those tests.

Interest was revived in 1942 after segmented seed had been introduced into widespread use. Number of seed per seed ball decreases with size of seed ball so that seed balls less than 2.5 mm. in diameter are practically all single seed. This fact has led to the suggestion that very small seed could be saved and, without being segmented, used alone or combined wtih seed that had been segmented. Furthermore, it was noted that with some cleaned but unsized seed lots high in average germination the very small seed removed in the standard sizing process could be blended back in without lowering the germination below the contract standard of 75 percent. An average of 3.5 percent of the totals passed through a 2.5 mm. screen and the germination varied from 50 to 75 percent. According to contract size standard these very small seed should have been discarded.

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[1]Agronomist and Principal Pathologist, Division of Sugar Plant Investigations, Bureau of Plant Industry, Soils, and Agricultural Engineering, Agricultural Reesarch Administration, U. S. Department of Agriculture.

This interest in seed ball size led us to start greenhouse and laboratory studies on size in relation to percentage and vigor of germination. Results of these tests led to field investigations of the matter.

Materials and Methods

The seed used in these investigations was produced in southern California, and western Oregon. Most of the seed lots used had been commercially cleaned according to contract standards, while one lot was used as it came from the thresher and without being commercially cleaned. The separation of the seed lots into different sizes was accomplished by passing them over screens with round holes of given sizes and then taking off in each case the seed that remained on top of the particular screen. The diameters of holes in the screens were 4 mm., 3.5 mm., 2.5 mm., and 2 mm. In one case a sixth size of seed was used, that passing through a 2 mm. screen. The sized seed was tested for germination on blotting paper so that the amounts of different sizes planted could be adjusted to the potential numbers of sprouts. The very small seed balls gave low percentages of germination and also relatively low numbers of sprouts per seed ball. Therefore, with the very small seed balls, many more were planted in a given length of row than with the large seed balls.

Greenhouse germination tests were made in soil in flats 14 inches wide, 16 inches long, and 3½ inches deep. Some of the seedlings from these flats were compared as to weight.

A field test was conducted at King City, Calif., using seed produced at Hemet, Calif., of the two varieties U.S. 22 and U.S. 33. Two sizes of seed of each variety were used: The larger seed was that remaining on a 4 mm. screen, the smaller seed was that passing through a 3 mm. screen and remaining on a 2.5 mm. screen. The plots were 65 feet long. There were four rows in each plot. The planting was on 2-row beds and the distance between the rows were 14 and 26 inches. The two entire center rows of each plot were harvested for yield data. Sucrose percentages and purity determinations were made by the usual standard methods. The plots were not replicated in this test but the soil was exceptionally uniform.

A field test at Riverside, Calif., involved U.S. 15 produced at Medford, Ore., and U.S. 33 produced at Hemet, Calif. Three seed sizes of each variety were used: The seed remaining on a 4 mm. screen; that passing through a 4 mm. screen and remaining on a 3.5 mm. screen; and that passing through a 3 mm. screen and remaining on a 2.5 mm. screen. The quantity of the smallest seed planted was increased in the effort to compensate for its lower germination. The plots consisted of two rows 65 feet long. The beets were thinned to

single plants 10 inches apart. Each treatment was replicated eight times.

Experimental Results

A test was conducted in the greenhouse with thresher-run seed of U.S. 33 produced at Hemet, Calif., and separated into six sizes. The sizes were: 4, 3.5, 3, 2.5, 2, and less than 2 mm. Enough seed balls, based on blotter germination tests, were planted in each row to give the same number of seedlings. In this soil test decrease in number of seedlings emerging and in vigar of seedlings become evident with the seed balls separated out by the 3 mm. screen. The smaller sizes were progressively poorer (figure 1).

A greenhouse germination test was conducted with three sizes of seed of U.S. 15 produced at Medford, Ore., and of U.S. 33 produced at Hemet, Calif. Each lot was separated into three sizes: 4, 3.5, and 2.5 mm. In both varieties the largest seed gave the highest germination and the seedlings were the most vigorous and most nearly uniform (figure 2). The seed were planted on April 11, 1944. On May 2 (21 days after planting) seedlings of each treatment were removed from the soil and carefully washed and weighed in lots of tens. Eleven such lots were weighed and the average weight per seedling, as given in table 1, was calculated from these weight determinations. The percentage germination decreased as seed size decreased. Seedlings from the 4 mm. seed balls were only slightly heavier than those from the 3.5 mm. seed balls but much heavier than those from the 2.5 mm. seed balls. Such seedlings when transplanted to pots and grown in the greenhouse continued to show the differences in size and vigor.

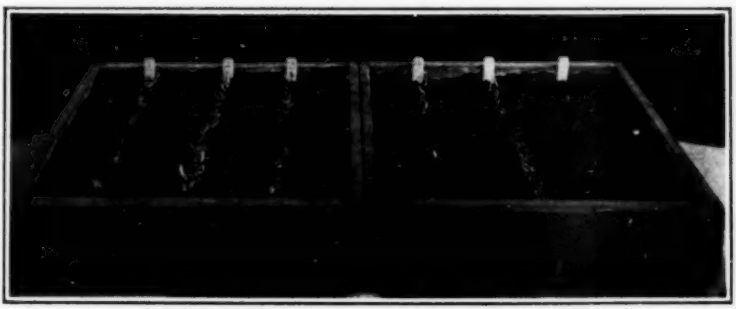

Figure 1.—Seed size in relation to germination and vigor with U. S. 33 grown at Hemet, Calif. Sizes, left to right: 4, 3.5, 3, 2.5, 2, and less than 2 mm. On basis of blotter tests, enough seed were planted in each row to give the same number of seedlings. Drop in germination and vigor begins with 3 mm. size.

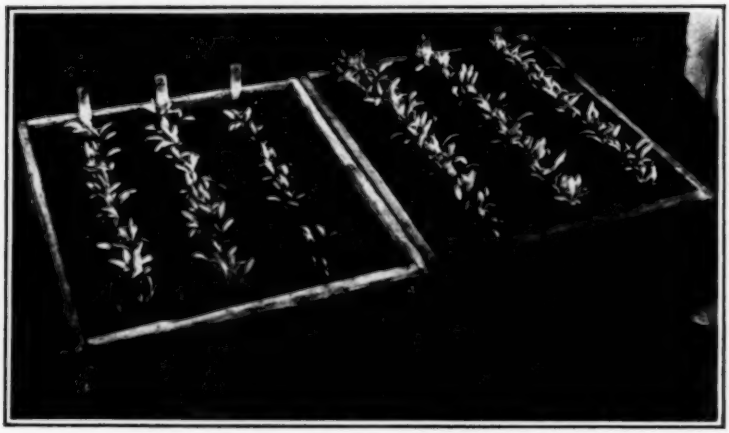

Figure 2.—Commercial seed of U. S. 15 grown at Medford, Ore., and U. S. 33 grown at Hemet, Calif., each separated, left to right, into three sizes: 4, 3.5, and 2.5 mm. U. S. 33 on right, U. S. 15 on left. Lowest germination and lowest vigor in smallest size in both varieties.

A field test was conducted at King City, Calif., in 1943. Seed of U.S. 22 and U.S. 33 produced at Hemet, Calif., were used. Two sizes, 4 mm. and 2.5 mm., of each variety were used. During the growing season it was noted that the plants from the smaller seed were very irregular in size while those from the larger seed averaged larger and were comparatively uniform. There was practically no difference in sugar percentage within the varieties but in both cases there was a noteworthy increase in yield from the larger seed, about 6 and 7.5 percent, respectively (table 2).

Table 1.—Seed size, germination, and vigor.

Variety and source	Seed size*	Average weight per seedling**	Germination
	Mm	Mgm	Pct
U. S. 15 (Oregon)	4	265	92
U. S. 15 (Oregon)	3.5	246	84
U. S. 15 (Oregon)	2.5	194	75
U. S. 33 (Calif.)	4	255	93
U. S. 33 (Calif.)	3.5	226	81
U. S. 33 (Calif.)	2.5	116	37

*Seed passed through round-meshed screens and then that remaining on respectives creens used.

**Results are averages from 11 ten-seedling samples for each seed size. Planted April 11, 1944. Weighed May 2, 1944.

Table 2.—Large and small seed test. King City, Calif. 1943.

Variety	Seed size*	Gross sugar per acre	Beets per acre	Sucrose
	Mm.	Tons	Tons	Percentage
U. S. 22	4	4.877	27.4	17.8
U. S. 22	2.5	4,636	25.9	17.9
U. S. 33	4	4.514	24.4	18.5
U S. 33	2.5	4.222	22.7	18.6

*Seed passed through round-meshed screens and then that remaining on respective screens used.

A replicated field test was conducted at Riverside in 1944. U.S. 15 seed produced at Medford, Ore., and U.S. 33 produced at Hemet, Calif., were used. Three sizes of seed balls were used of each variety: 4, 3.5, and 2.5 mm. Even though a heavier rate of planting was used with the smallest seed the seedlings did not emerge as thickly in those plots as they did in plots from the two larger sizes. This thinner stand in the plots from the smallest seed resulted in less competition during pre-thinning stage than was the case with the thicker stands of more vigorous seedlings in the other plots. If there was any considerable effect from the difference in competition before thinning, the advantage was in favor of the smallest seed. The difference between size of tops of plants from the 4 mm. and the 2.5 mm. seed was obvious until late summer (figure 3). The harvest data from this test are given in table 3. There were no significant differences in

Table 3.—Seed size in relation to yield of sugar beets. Riverside, Calif., 1945.*

Variety and source	Seed size**	Sugar per acre		Beets per acre	Sucrose	Purity	Beets per 100 feet of row
		Available	Gross				
	Mm.	Tons	Tons	Tons	Percentage	Percentage	
U. S. 15 (Oregon)	3.5	4.549	5.260	32.94	15.98	86.49	114
U. S. 15 (Oregon)	4	4.483	5.175	32.97	15.70	86.66	116
U. S. 15 (Oregon)	2.5	4.254	4.918	30.65	16.07	86.52	114
U. S. 33 (Calif.)	4	3.905	4.570	31.25	14.65	85.49	115
U S. 33 (Calif.)	3.5	3.886	4.600	32.35	14.24	84.47	114
U. S. 33 (Calif.)	2.5	3.747	4.399	29.71	14.83	85.16	114
Diff. for Sig. (19:1)		.141	.186	.932	.66	ns.	

*Data are averages of eight replications for each seed size.
**Seed passed through round-meshed screens and then that remaining on respective screens used.

Figure 3.—U. S. 33 plants from two seed sizes: Two rows on left from 4 mm. seed, two rows on right from 2.5 mm. seed. Seed produced at Hemet, Calif. Planted at Riverside, Calif., March 27, 1945. Photographed May 16, 1945.

sucrose percentages and purities and no significant differences in yield between the 4 mm. and the 3.5 mm. sizes in either variety. However, the yields in both varieties were significantly lower in the 2.5 mm. sized lots, 7 percent in U.S. 15 and 6 percent in U.S. 33.

Discussion and Conclusions

Rapid germination is a very important characteristic of sugar beet seed because seed bed conditions favorable at the time of planting may soon become unfavorable. The larger seed balls are preferable because the seed in them germinates faster than that in the small seed balls. Vigorous seedlings, such as the larger seed balls afford, are advantageous under many circumstances, as, for example, when there is soil crusting or insect attack.

Gains in yields of beets and sugar accruing from use of the larger seed far more than offset losses involved in discarding the smallest and weakest seed. Where seed is to be segmented it would seem obviously advantageous to size the seed first, discard the smaller seed, and segment only the larger seed.

If the indicated advantages justify a higher standard for seed size an increase in the amount of seed grown will become necessary.

The evidence presented in this paper suggests that the size standards that ought to be applied may differ for different seed-growing regions.

Summary

Sugar beet seed size studies in the greenhouse and field revealed that seed balls remaining on 4 mm. and 3.5 mm. round-hole screens had faster germination and gave more vigorous seedlings and higher yields than did seed balls remaining on a 2.5 mm. round-hole screen. Under critical greenhouse and laboratory examination and with seed of the variety U.S. 33 grown at Hemet, Calif., it was found that seed balls remaining on a 4 mm. round-hole screen had higher germination and gave more vigorous seedlings than did seed balls passing through the 4 mm. and remaining on the 3.5 mm. screen. The one replicated field test involving these two sizes and from two varieties did not bring out a statistically significant difference in yield between these two sizes.

Size of Seedball in Relation to Yield of Sugar Beets

H. L. Bush and H. E. Brewbaker[1]

Precision planting appears to be one of the most important factors in the mechanization of the beet crop. Since some form of sizing or grading of the seed is essential to uniform planting it is important to know whether or not any yield differences are to be expected from different sizes of seed.

The problem of securing adequate stands with small seed is important because of a recognized tendency toward lower germination and also in some part because of smaller germs in the small seed. A pertinent test conducted at this Station in 1912 included two European varieties, R & R "Normal" and Breustedt. Results are presented in table 1.

Table 1.—Relative size of seedballs and germs.

	R & G "Normal"			Breustedt		
Germs per ball	No. balls	Balls Ave. wt.	Germs Ave. wt.	No. balls	Balls Ave. wt.	Germs Ave. wt.
		Grams	Grams		Grams	Grams
1	5	.0212	.00264	7	.0124	.00178
2	9	.0179	.00223	19	.0171	.00188
3	7	.0311	.00262	26	.0308	.00220
4	12	.0542	.00339	5	.0330	.00234
5	2	.0558	.00270	3	.0549	.00281
6	1	.0900	.00380	—	—	—

The number of comparisons is rather small as indicated by the number of seedballs in each class but there is a tendency for the germ size to increase with the larger seedballs.

Similar but more extensive work was conducted at this Station in 1920 using two lots of seed germinating 71 percent and 36 percent, respectively. The results for this study are presented as averages of 50 seedballs for each class in table 2.

The seedballs were classified as to number of germs by seed "caps", as well as number of sprouts produced. It is noted that with few exceptions the tendency toward larger germs in larger seedballs is in agreement with the results as recorded in table 1.

Studies conducted at this Station in 1910 and 1911 and again in 1940 furnish some data pertinent to the question of the yielding ability of beets growing from seed of different sizes. For each of

[1]Statistician-Agronomist and Director, respectively, Experiment Station, Great Western Sugar Company, Longmont, Colo.

Table 2.—Comparison of germ and seedball weights for 71 percent- and 36 percent-germination seed.

Kind of seedball	Ave. wt. per seedball		Ave. wt. per germ	
	71%	36%	71%	36%
	Grams	Grams	Grams	Grams
1 germ 1 sprout	.00503	.00574	.00213	.00184
2 germs 1 sprout	.01178	.01085	.00235	.00195
3 germs 1 sprout	.01365	.01458	.00233	.00207
4 germs 1 sprout	.01686	.02150	.00241	.00258
2 germs 2 sprouts	.01138	.01211	.00236	.00207
3 germs 2 sprouts	.01375	.01734	.00217	.00219
4 germs 2 sprouts	.02087	.02364	.00233	.00242
3 germs 3 sprouts	.01740	.01925	.00230	.00207
4 germs 3 sprouts	.02207	.02614	.00234	.00244
4 germs 4 sprouts	.02366	.02568	.00238	.00248

these tests sufficient seed was planted to assure a good thinned stand for each size of seedball.

The test in 1910 consisted of eight replicates of plots 50 feet in length in which "small", "medium", and "large" seed of the same variety was tested. The "small" seed passed through a 6-mesh (about 8/64 inch) (3.17 mm.), the "medium" passed through a 4-mesh (about 12/64 inch) (4.76 mm.) and remained on a 6-mesh, and the "large" remained on a 4-mesh sieve. The results for this test are presented in table 3.

Table 3.—Results for seed size test, 1910.

Seed size	Beets per A.	Sugar	Beets per 100 feet of row
	Tons	Percent	No.
Small	16.91	16.78	127
Medium	16.95	16.85	127
Large	15.81	16.66	109

It is doubtful if any significant differences exist between yields. The lower yield for "large" seed may possibly be attributed in part at least to the difference in stand.

In 1911 this test was repeated, except that only two replicates were planted. The results for this test are presented in table 4.

Table 4.—Results for seed size test, 1911.

Seed size	Beets per A.	Sugar	Beets per 100 feet of row
	Tons	Percent	No.
Small	17.66	18.01	124
Medium	17.80	18.02	138
Large	18.54	18.05	138

It is safe to assume a high random error for this test, so in all probability no significant differences exist. It may be noted, however, that the "large" seed produced the highest yield in direct contrast to the 1910 results (table 3).

The size-of-seed test in 1940 was combined with the regular variety test, which was an eight x eight triple-lattice design with nine replicates. Plots, as harvested, were four rows x 30 feet with the entire plot being taken for yield and the two center rows used for sugar analysis. The "large" seed remained on a 13/64" (5.16 mm.) screen and the "small" passed through a 9/64" (3.57 mm.) screen, with three different varieties being used. These results are presented in table 5.

Table 5.—Results for seed size test, 1940.

Variety	Seed size	Beets per A. Tons	Sugar Percent	Sugar per A. Lbs.	Beets per 100 feet of row No.
A	Large	26.52	12.27	6508	100
	Small	26.34	12.38	6522	97
B	Large	25.56	12.53	6405	99
	Small	26.14	12.17	6362	95
C	Large	25.32	12.78	6472	100
	Small	25.33	12.66	6414	97
LSD 5 percent pt.		.56	.34	268	....

This test was well conducted and a very low standard error resulted. The "small" seed of Variety B produced just significantly more yield than the "large" seed of the same variety but in this case the sugar percentage was just significantly higher for the "large" seed, with the result that there was no difference in pounds sugar per acre. No difference existed between the seed sizes for either of the other two varieties.

It is quite evident from the data herein presented that no yield differences due to any inherent genetic reasons may be expected among various grades or sizes of seed but it is expected that more care must be exercised with smaller seed sizes in order to assure stands comparable to those from large seed.

Factors Influencing Sugar Beet Seed Production in Arizona and New Mexico

A. A. Mast[1]

Since the introduction of the sugar beet seed industry in southwestern United States, Arizona and New Mexico have produced nearly 73,000,000 pounds of sugar beet seed. This is approximately two-thirds of the total amount of beet seed grown in the United States and represents about a 5-year supply of seed based on pre-war planting requirements of the domestic beet sugar industry. Considering the limited amount of agronomic research work done on the overwintering method of beet seed production, it is remarkable that in the comparatively short period of 10 years so much progress has been made in increasing the production of seed per acre.

The present methods have evolved mainly from trial and error. Since the Western Seed Production Corporation is primarily a commercial beet seed producer, the personnel has not been available to carry out carefully controlled experimental work. However, the field force has consistently studied the crop through the years and from their experience and observation definite ideas have been developed as to the factors which affect seed production.

Land Selection

The following must be taken into consideration in selecting land suitable for production of sugar beet seed: Type of soil, levelness and drainage, previous cropping history, natural fertility, and location within the area.

Only loam soils should be chosen for production of beet seed, preferably silty clay loams or those approaching that texture. Land also should be quite level; a fall of about 4 feet to the mile is considered ideal. Though fields sufficiently flat to insure adequate intake of water are preferred, sufficient drainage is essential to best results.

A previous cropping history which includes truck crops is preferable in those areas where vegetables are grown, both from the standpoint of freedom from weeds and improved residual fertility due to heavy fertilizer applications normally made to those crops.

Natural fertility, of course, varies greatly between individual fields, and only those having high fertility should be chosen for beet seed production because no reasonable amount of commercial fertilizer can compensate for lack of inherent fertility.

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[1]Manager, Western Seed Production Corporation, Phoenix, Ariz.

In each district where seed is grown certain areas have been found which constantly outperform others for a number of reasons. In the Phoenix district particularly, where temperatures are a greater factor than in any of the others, certain locations in the valley have been found which are subjected to lower winter temperatures. By confining beet seed growing to the colder areas, the percentage of bolting and the yields of seed have been materially improved. It is also true that certain areas will be subjected to influx of greater leafhopper populations because of their proximity to the natural breeding grounds and to the fact that migrating leafhoppers have a tendency to follow more or less fixed routes.

Date of Planting

The trend throughout the years has been toward earlier planting. Planting generally starts in all areas around August 15 and for the best results should be completed by September 10. Early planting appears to be just as important in the Salt River Valley (Phoenix district), which has an annual mean temperature of 69° as in Albuquerque, N. M., which has an annual mean temperature of 58°.

The main advantages of early planting are: First, an extension of the photoperiod; second, early and rapid development of foliage prior to the winter months; and third, increased root development.

It is generally recognized that the photoperiod is one of the chief factors influencing bolting. Early planting naturally increases the photoperiod by the plants being subjected to a longer period of sunlight prior to the bolting period.

Early and rapid development of foliage has a number of advantages. First, it provides an unfavorable environment for the sugar beet leafhopper native to all areas; second, it discourages the growth of fall and winter weeds; and third, it provides a good foliage cover during the winter months which tends to maintain a uniformly low soil temperature during the dormant period, which is also conducive to bolting.

Increased accumulation of food within the root prior to the bolting period will naturally result in a more vigorous plant at fruiting time.

Stand

The types of planters generally used throughout the areas do not permit positive spacing as is possible in some types of planters used in commercial beet planting. As a result, in order to insure uniform stands, more seed per acre must be applied than is desirable. The planting rate, however, has been constantly reduced during the years.

With good-quality, high-germinating seed, 10 to 12 pounds per acre rate is sufficient. A stand of 4 to 6 beeets per foot uniformly spaced in 20-inch average rows will give the highest yield and will produce seed most nearly like that planted. If the stand is too heavy, the competition between individual beets will smother out a certain percentage of the individual plants. Elimination of any plants has a tendency to change the genetic nature of the seed harvested. On the other hand, a stand too light to give complete shading will result in a condition which is favorable for harboring the beet leafhopper and will allow soil temperatures to rise above the point where complete bolting is obtained.

Fertility

Phosphatic fertilizers applied in a ribbon under the seed prior to planting is the recommended practice. From 40 to 60 pounds of P_2O_5 per acre, depending on previous crop and individual field history, is considered adequate in most cases. A fall application of at least 40 pounds nitrogen has been proved necessary in order to obtain rapid development of root and foliage and to maintain foliage development during the period of dormancy. Should the crop, during the winter months, exhibit a nitrogen deficiency, as evidenced by yellowing of the foliage, a mid-winter application of 30 to 40 pounds per acre of nitrogen in nitrate form is applied. In order to initiate and hasten new growth in the spring a minimum of 40 pounds of nitrogen is again applied as soon as temperatures are favorable for growth. To prevent any slowing down of growth prior to maturity, another similar application of nitrogen is made about 6 weeks prior to harvest. Individual fields showing marked nitrogen deficiency are given still more nitrogen throughout the season. As much as 200 pounds of nitrogen has been applied during the season to fields in this category with highly satisfactory results. In the Phoenix area all spring applications of nitrogen are made in the irrigation water because heavy foliage growth does not permit mechanical application.

Weather

To obtain complete bolting of plants, it is essential that they have ample cold exposure and light. In Arizona, and the Phoenix district in particular, winter temperatures are not always sufficiently low to maintain a uniformly low soil temperature. The damage resulting from too high winter temperatures can be minimized by following the practices mentioned, these being early dates of planting and high fertility which assure rapid growth to provide complete shading early in fall. During a season in which humidity is extremely low and temperatures extremely high, these factors can be compensated for

in part by increasing the frequency of irrigations, particularly during the seed-setting and seed-maturing period.

Irrigations

The bed method of planting is used exclusively in Arizona and is constantly gaining favor in the New Mexico area. This method of planting has a number of advantages over flat planting in sugar beet seed production, the greatest of which is the provision of a sufficiently large furrow to permit uniform irrigations without flooding. Frequency of irrigations is naturally determined by soil types and prevailing weather conditions. In general, intervals of 8 to 20 days between irrigations during the fall and spring months and 20 to 60 days, depending on the area and natural rainfall, during the winter months are productive of best results. The amount of water required to produce a beet seed crop ranges from 2 to 4½ acre-feet, depending on the season and the area.

Insects

Insects of major importance are the sugar beet leafhopper and lygus bugs. The garden webworm, the beet army worm, and several of the cutworms occur sporadically but are usually of minor importance.

The sugar beet leafhopper, indigenous to all areas in which the Western Seed Production Corporation operates, presents a real problem in sugar beet seed production. The control of this insect until recently has been accomplished by the application of an atomized pyrethrum-oil spray. This material, when properly applied, has always given very good kills. However, the leafhopper is of a migratory nature and too often fields are reinfested after having been sprayed. Experience has shown that once complete coverage of row is obtained, protection against reinfestation is assured. Therefore it is imperative to secure complete coverage of row by foliage as quickly as possible.

During the past 2 years, through the co-operation of the Bureau of Entomology and Plant Quarantine, experimental work has been conducted using a 5-percent DDT dust as a substitute for pyrethrum-oil spray. Though results have not always been perfect, control in general has been as good if not better than with the pyrethrum-oil spray. This has not been because of superior kills but because of the residual effect peculiar to DDT which the pyrethrum-oil spray does not have. The application by plane of 30 pounds per acre of a 5-percent DDT dust has given good results. This has provided sufficient residual effect to give adequate control until such time as foliage

development protects the crop against damage from this insect. This Fall approximately 1,500 acres of sugar beet seed in Arizona were so treated and the results were gratifying.

The standard control for the beet army worm and the garden webworm has been with arsenicals. However, it was observed this last fall that 5-percent DDT dust used for leafhopper control was equally effective against these two insects. The only satisfactory means of control for the cutworms found to date has been with poison bait.

The damage done to the beet seed crop by lygus bugs has been pointed out in recent years by workers of the Bureau of Entomology and Plant Quarantine. This work started in 1938, and lygus has since come to be recognized as an important factor affecting germination of sugar beet seed. This past season, except for check plots, the entire beet seed acreage grown in the Salt River Valley of Arizona was treated for control of this insect using 30 pounds per acre of 5-percent DDT dust. On 10 fields from which beet seed germination analyses were obtained, from treated and untreated portions, the average germination on the treated portions was 81.5 percent and the average on the checks was 53.7 percent, or a difference of 27.8 percent due to treatment. Work done to date indicates that dusting as soon as flowering begins, with a 5-percent DDT dust or an equally effective dust, will become a standard practice in all areas with the possible exception of the Mesilla Valley in New Mexico where injury to the crop by lygus has not been a serious problem to date.

Harvesting Methods

In order to obtain high yields of good germinating seed, harvesting and threshing must be timely. Through the initiative of the beet seed growers in the Salt River Valley of Arizona, mechanical harvesters and traveling threshers have been developed to a point where they are quite efficient. It is general belief that these developments have done much in increasing seed yields per acre. The use of this equipment has resulted in a minimum handling of the crop, has eliminated much hand labor (which has been practically unobtainable during the last few years), and has stepped up the date of completion of seed harvest.

Conclusion

Good farming practices applicable to any other crop, together with heavier than average fertilization with nitrogen, will produce good results in the production of the beet seed crop in the areas served by the Western Seed Production Corporation. However, the sugar beet seed crop requires closer attention to minute details than does the average crop. Without question, there is still much to be learned and further refinements will undoubtedly be made in growing and handling of the beet seed crop.

Sugar Beet Seed Growing in the Pacific Northwest[1]

RAY A. PENDLETON[2]

The development of the sugar beet seed industry in this country has been mainly by the method of overwintering in the field. This involves selection of locations with suitable climatic conditions to insure reproduction. Studies by Owen and other (*1*)[3] have shown that a winter temperature of 35° to 45° F. for 2 or 3 months, thus holding the beets semi-dormant, is desirable to insure complete reproduction. Inadequate thermal induction of flowering tends toward elimination of those types that are low in bolting tendency and thus develops faster bolting varieties. Parts of the Pacific Northwest have winter temperatures within this favorable range, and beets may be overwintered in the field without danger of winter killing from freezing (figure 1.)

Along with a suitable climate, there must be soils adapted to the crop. The stream bottom soils such as those of the Medford series in southern Oregon, Chehalis, Newberg, and Hillsboro in the Willamette Valley, Puget in western Washington, and several others less well known, are adapted for sugar beet seed culture. All these soils have their specific nutritional problems. Many western Oregon soils have a deficiency of sulphur. Heavy winter rains have caused considerable leaching, causing is some areas deficiencies of nitrogen, calcium, boron, and other nutrients, and resulting in unfavorable soil acidity. Phosphorus and potash are not abundant but appear to be sufficient for present needs on most of the river bottom soils in Oregon. Some soils of western Washington have a pronounced phosphorus deficiency.

In the Willamette Valley beets sometimes fail in the seedling stage because of shortage of sulphur. Heavy nitrogen fertilization in the spring without adequate sulphur may result in sulphur deficiency symptoms later. Such deficiency may be reflected in extreme chlorosis, deformity of heads, susceptibility to disease, general low yield, and poorer quality seed. Gypsum applications (100 to 200 pounds per acre) broadcast prior to planting will take care of the seedling stage. Where a considerable quantity of commercial nitrogen is used in the spring, at least one-third of it should be in the sulphate form in order to maintain sulphur supply.

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[1]Experimental work done in cooperation with the Oregon Agricultural Experiment Station, Corvallis, Ore.

[2]Associate Soil Technologist, Bureau of Plant Industry, Soils, and Agricultural Engineering, Agricultural Research Administration, U. S. Department of Agriculture.

[3]Italic numbers in parentheses refer to literature cited.

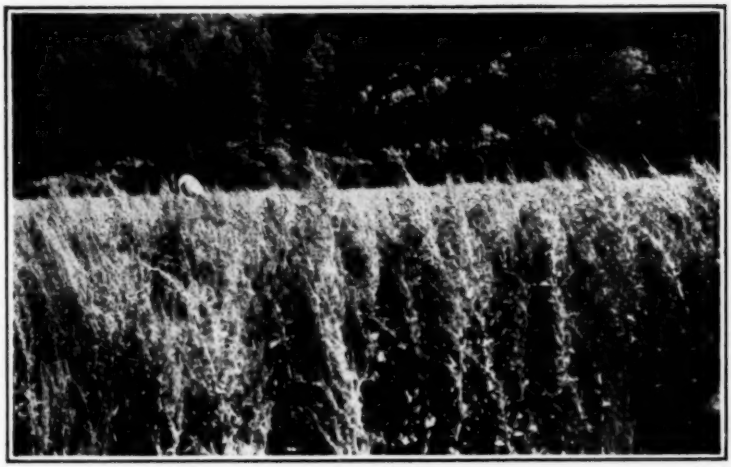

Figure 1.—The sugar beet variety, Improved U. S. 15, as grown for seed at Gold Hill, Ore. Photographed June 18, 1943, on the farm of Otto Bohnert.

Boron deficiency is readily corrected by the application of 25 to 30 pounds of borax per acre. This should be a general practice on all Willamette Valley soils because without added boron serious malnutrition may develop. This malnutrition takes the form of heart rot and winter killing or may result in terminal shoot deformation in the seed stalk phase.

Soils of western Oregon have for the most part been under cultivation for many years and with insufficient effort being made to maintain the original natural fertility. Organic matter has become deplented, plow soles have developed, soil structure has suffered, and nutrients have ben lost. Low yields have resulted. However, 3,000 to 5,000 pounds per acre of high quality seed grown in some places indicate the potential capabilities of the area. The sugar beet crop under good conditions makes a large amount of vegetative growth, and heavy fertilizing with commercial nitrogen is necessary. From 100 to 200 pounds of nitrogen per acre are usually required. A small portion of this should be applied in the fall, but the major portion should be side-dressed in the spring. Where irrigation is practiced, a small amount, preferably in nitrate form, applied through the irrigation water will be highly beneficial. Fall treatments should be in the sulphate form to prevent loss by leaching, but for spring side-dressings best results have ben obtained with a mixture of ammonium sulphate and sodium, ammonium, or calcium nitrate.

In the overwintering method of production practiced here, seed is planted at rates ranging from 10 to 15 pounds per acre in rows

spaced 20 to 28 inches and left unthinned. A few fields have been cross blocked under non-irrigated conditions to provide hills at 24 inches by 24 inches spacing. Yields under this method have been comparable to continuous planting with similar soil conditions. Where this is contemplated the grower should strive for a stand of 6 to 8 plants per hill. Investigations with stand variations have not shown any marked yield differences over a moderate stand range.

Considerable latitude in planting season is possible, although the main part of the crop in this area has been planted in the fall. In southern Oregon plantings have been in the fall following pre-irrigation, but in the Willamette Valley plantings from June 1 to the middle of August have been about uniformly successful. Plantings up to the middle of June can usually utilize spring moisture for germination, and yields up to a ton of seed per acre may be grown without irrigation. Plantings later than this will usually require irrigation for germination. Plantings earlier than June 1 may suffer considerably from leaf spot diseases or winter killing. Plantings later than the middle of August may not attain sufficient root growth for satisfactory seed yields. Supplemental irrigation during the period of greatest vegetative growth is profitable.

The weed problem requires special attention because the relatively mild winter temperature of this area is favorable for weed growth. Crop sequence should be planned so as to contribute to weed control. Beets should not follow a spring grain. Late August plantings may not make sufficient growth to hold weeds in check. Cultivation as late in the fall and as early in the spring as the condition of the soil will permit will aid materially in weed control. Where good farming is practiced the weed problem is negligible.

Harvesting in this area usually starts about the latter part of July or the early part of August. This has been handled most satisfactorily by swathing with a special cutter, after which threshing can be done with an ordinary combine. If more capacity is desired, large stationary threshing machines have been remodeled, provided with pick-up attachments and suitable running gear so as to be satisfactory for this work.

About 2,000 acres of sugar beet seed were produced in the Pacific Northwest in 1941, but some decline was experienced during the war. With an expected resumption of normal beet sugar production and with better cultural programs established, this crop should have an expanding place in sound rotation practices for this area.

Literature Cited

1. Owen, F. V., Carsner, Eubanks, and Stout, Myron. Photothermal Induction of Flowering in Sugar Beets. Jour. of Agr. Res. 61: 101-124. 1940.

The Importance of Standardized Germination Methods in the Marketing of Sugar Beet Seed

BETTY RANSOM ATWATER[1]

A standardized germination method for sugar beet seed testing is essential to efficent marketing and interchange of seed. A great deal of misunderstanding and expense could be avoided in the industry if a simple and effective testing technique were to be adopted by all laboratories concerned. The recommendations made under the Federal Seed Act have been adopted by most laboratories in the country.

The exactness of seed testing as a measure of the value of any given lot of seed is complicated by a number of factors. In the first place one may expect inherent variation in any plant material. This natural variation in seeds may be increased by conditions at maturity and harvest or by the technique of cleaning and blending. Assuming that the lot is of fairly even quality to begin with and that any blending that has been necessary has been done as carefully and thoroughly as possible, we still must draw a working sample of a pound or two of seed from several thousand pounds in the original lot. This working sample is then carefully mixed and divided until only 400 seeds are selected indiscriminately for use in determining the germination of the entire lot. If in addition to these factors each analyst develops an individual technique in determining germination, the results are likely to be confusing to say the least.

A number of years ago the government took over the responsibility of seed inspection in an effort to improve the quality of seed for sale. Laws were passed concerning the proper labeling of seed as to purity and germination and requiring that it be free from certain noxious weeds. For the enforcement of these laws it was found necessary to set up laboratories and develop laboratory techniques for determining the purity, germination, and noxious weed content of seeds which came under their observation. During the years that followed the correlation of individual and federal research led to a definite recommendation of procedure in making laboratory tests on seed. When the new Federal Seed Act was adopted several years ago there were accompanying methods of testing for the enforcement of the act. These rules were drawn up with the greatest of care and were formulated, checked, and approved by both the commercial and official seed-analyst associations. These rules are

[1]Manager, Ransom Seed Laboratory, Los Angeles, Calif.

amended from time to time as it seems necessary. The federal government has urged that all laboratories follow these procedures as closely as possible so that a measure of uniformity may be achieved in complying with and in enforcing the law. Sectional schools are conducted each summer and a representative from the Washington laboratory is present to help analysts arrive at uniform interpretations of laboratory tests. In addition, photographic plates have been made showing normal and abnormal types of sprouts which may occur in the germination tests of various kinds of seed. Referee tests on different seeds are out regularly to all members by both analyst associations for experiment and regular test. The results are published so that participants may compare their work with others and benefit by the discussions and recommendations made by the research committees.

These efforts toward the development of uniform results in seed testing are important to the seed trade so that it may have reliable information for buying and selling seeds as well as fair judgment from law enforcement officials.

I believe that all organizations should strive to follow the rules and regulations for seed testing as they have been set forth by federal authorities. If it is found that these rules are impractical or unfair, the matter should be brought to the attention of the official seed analysts' research committee and changes recommended through the proper channels so that difficulties will not arise through lack of uniformity in methods used in different laboratories.

It is our experience and belief at the Ransom Seed Laboratory that the present official method of testing beet seed is efficient and practical as well as consistent in result. It consists, as you know, of testing 400 seeds. These are soaked in tap water at room temperature for 2 hours. They are then drained and put between saturated germinating blotting paper and placed on trays in a germinator thermostatically controlled to maintain a temperature of 30° C. for 8 hours and 20° C. for 16 hours. The time for the test is 14 days. Retests shall be made if there is a difference of 10 percent between any two of the separate hundred seeds tested when the average of the tests is 80 percent or above, and if there is a difference of 15 percent when the average is below 80 percent; otherwise, the average of the tests shall be considered the result of the test.

At the Ransom Seed Laboratory we have found that 100 seeds may be soaked in a 100-cc. test tube. At the end of 2 hours these are drained into a strainer, rinsed under the tap, and blotted on a paper towel to remove the excess moisture; then they are arranged between

folded blotters. Counts are made at 3, 5, 7, 10, and 14 days. Most of the germination has occured by the sixth day.

We have periodically participated in tests submitted to different laboratories from the same sample and have found the results satisfactory when all laboratories concerned use the official method. Tests were made in this manner with the California state laboratory over a 2-year period involving several hundred tests. The average for each year varied less than 3 percent, and less than 10 percent of the individual tests varied more than the allowable tolerance which are as follows:

	Tol.		Tol.
96 or over	5	70 or over but less than 80	8
90 or over but less than 96	6	60 or over but less than 70	9
80 or over but less than 90	7	Less than 60	10

In conclusion, we would like to recommend that the Association of Sugar Beet Technologists adopt the official method of testing sugar beet seed.

Standard Methods of Laboratory Germination of Sugar Beet Seed in Canada

K. W. HILL[1]

In Canada seed traffic and merchandising are rigidly controlled by federal statute. Until the last decade almost all sugar beet seed used in Canada was imported from Europe, and consequently purity standards have been established to which strict adherence is maintained.

Laboratory Methods For Regular Seed

Screening.—A seed sample presented for germination may be screened over a screen of 2-millimeter mesh to remove light dust.

Soaking.—Four samples of 50 seeds each are then selected and each sample is set to soak in a separate aluminum cup containing at least 50 cc. of tepid water. The first water is changed after soaking approximately three-quarters of an hour, and thereafter the water is changed every hour throughout the soaking period which must be at least 3 hours but not more than 6 hours. After soaking, the seed is thoroughly drained over a wire mesh before planting.

Planting.—Each sample is planted between blotters and germinated at a temperature of 20° to 30° C. The temperature is allowed to rise gradually in the morning and fall gradually at night, one complete cycle being made each 24 hours. The blotters used are prepared specially and are meant to be free from active nitrogenous or sulphurous substances.

[1]Agronomist, Dominion Experimental Station, Lethbridge, Alberta, Canada.

Counting.—Counts are made at 3, 5, 7, and 10 days; seed pieces which do not produce normal radicles are not considered.

Pre-chilling.—When newly harvested seed is being tested, a duplicate sample is pre-chilled at 7° C. for 4 days and then germinated at the same time as the unchilled sample. If there is a discrepancy between these duplicate samples the pre-chilled one is considered the more accurate.

Segmented Seed

The same general laboratory methods are followed with segmented seed as with whole seed. However, it is felt necessary to allow further elongation of radicles from segmented seed pieces of questionable normality than is considered necessary with entire seed.

Purity Analysis.—All seed submitted for germination test in Canada is subjected to a purity analysis. This fact has introduced a complication in germination tests of segmented beet seed. According to rule any material which is not a true seed is classed as inert material. In the cereal grain analyses a broken kernel is not counted if it is less than one-half kernel. With segmented sugar beet seed the empty pieces of pericarp of comparable size to the seed pieces constitute a problem. The analyst would normally remove these as inert material but if this is done the laboratory germination percentage will not be truly related to the field germination since these empty pieces of pericarp would be metered out by the drill with the same readiness as would pieces of comparable size containing true seed.

Comparison of Methods Employed in the Germination of Beet Seed

R. S. LAMBDIN[1]

During past years a considerable amount of beet seed had been reported as having a rather low germination. In many cases field plantings of this seed produced excellent stands, considerably better than was expected on the basis of the germinations reported. Therefore it seemed advisable to attempt to find methods of testing seed which would more nearly duplicate maximum field emergence in the greenhouse and to compare these tests with those of commercial laboratories.

Materials and Methods

A medium sandy loam soil was employed in the greenhouse emergence studies. The pasteurizing was sufficient to control all soil-borne disease-causing organisms and to make non-viable any weed seed present. The flats were made of galvanized sheet metal and were 6 inches wide, 8 inches long, and 2 inches deep. An inner removable partition, also of galvanized metal, divided the flat into 100 small rectangular compartments. The partition was only 1½ inches high. Hence, when it was in the flat a ½-inch space was left on top to facilitate watering, etc. After the partition was inserted the flat was filled with soil by sifting the damp soil into the compartments through a ⅛-inch mesh hand screen. Enough soil was sifted into the flat to reach the top level of the partition. In order to insure a definite planting depth the soil was packed somewhat by means of a wooden tamper.

The seed tested was taken from commercial lots and the data reported in this article were taken from the tests run on the seed used to plant the 1945 sugar beet crop grown for the Spreckels Sugar Company. A representative 1-pound sample was taken from each lot to be tested. Half of this sample was sent to a commercial seed laboratory for the standard germination tests. Thus the design of the experiment was that of a randomized complete block in which the variability due to differences between samples was controlled. Four hundred seed units were used in the soil tests, one unit being planted in each rectangle of the 4 flats having 100 rectangles each. The seed units were placed on the soil surface and sufficient water was added to bring the soil moisture content up to its water-holding capacity. Then the seed units were covered with screened soil to a depth of ½ inch. The flats were covered with burlap and further watering was

[1]Assistant Agricultural Superintendent, Spreckels Sugar Company, Spreckels, Calif.

not necessary until the fifth day. Water was added daily, including the fifth day, until the tenth day when final counts were made. Injured seedlings were not included in the emergence counts.

Both sheared and whole seed were used in the studies.

The analysis of variance was used in reducing the data and any differences discussed in this article will have been found to be statistically significant unless a statement to the contrary is added. Differences giving odds as great as, or greater than, 19 to 1 against the deviations noted being due to chance were considered as statistically significant. The standard errors are given for the averages of table 1.

Results

The reduced data showing the results of the study are given in table 1. These results are indicative of the necessity of germinating seed under conditions which will bring out more closely the seeds' ability to emerge in commercial field plantings.

Table 1.—Comparisons of germination means at Spreckels and commercial laboratories.

Sheared seed Variety and lot number	Number of tests	Germination percent			Range of germination	
		Spreckels	Commercial laboratory	Difference	Spreckels	Commercial laboratory
U. S. 15-2272A	3	87	76	11	4.50	8.25
U. S. 15-3251	3	83	79	4	1.75	4.00
U. S. 15-3254	4	86	75	11	7.25	5.75
U. S. 15-3280E	4	89	79	10	1.00	5.00
U. S. 15-3280D	20	88	81	7	4.25	8.00
U. S. 15-1008	16	81	68	13	7.00	21.75
Average		85.48±0.528	75.56±0.528	9.92±0.746		
Whole seed	27	80.33±0.562	77.67±0.562	2.66±0.795		

Note: All Spreckels tests were conducted in soil for a 10-day period. Commercial laboratory tests are 14-day tests.

The increased percentage germination in the soil test over commercial tests of 9.92 in sheared seed and only 2.66 for whole seed is to be expected because of the difference of the number of sprouts per seed unit. The sheared seed used in these tests averaged 1.38 seedlings per unit, whereas whole seed will average approximately 2 seedlings per unit.

Beet Seed Germination Technique Used By the Utah-Idaho Sugar Company

ROBERT S. GADDIE[1]

In general the procedures used by the Utah-Idaho Sugar Company in laboratory germination tests of sugar beet seed are those recommended by the Committee on Standardization of Experimental Methods (*1*)[2] and of Tolman and Stout (*2*) and (*3*). We have done considerable experimental work on beet seed germination and have verified the results which led to these recommendations. All of our germinating is done in blotters (6 inches by 9½ inches, 120 pound) in a Minnesota Seed Germinator at a temperature of 25° C. The washer which we built for washing the seeds consists of a rectangular galvanized iron container 18 inches by 6½ inches by 2½ inches with a false bottom soldered 1 inch above the true bottom. On 1½-inch centers in the false bottom are drilled 1/16-inch holes. A ⅜-inch inlet pipe is soldered in one end under the false bottom. The outlet consists of a spout or spillway 6 inches wide cut down ½-inch from the top on the other end. The washer holds 40 small square wire baskets made from Tyler Ton-Cap screen similar to that used on the Roball sugar sifters. These baskets are 1½ inches by 1½ inches by 2 inches high and fit directly over the 1/16-inch holes in the false bottom. Water enters the inlet pipe and is forced through these holes in the form of a jet keeping the seed contained in the basket agitated during the washing. The amount of agitation may be regulated by the amount of water entering under the false bottom.

Whole Seed

The sample of seed is split in a riffle sampler (½-inch riffles) until 200+1 to 10 seedballs remain. A little practice will enable the operator to obtain very close to the requisite 200 seedballs. This, we believe, goes a long way toward eliminating the personal equation in selecting 200 seedballs from a lot. Two lots of 100 seedballs each are counted out, placed in the small wire baskets, and washed from 2 to 4 hours. At the end of this washing period the baskets are taken out of the washer and placed on a towel to absorb the excess water and the seeds are allowed to dry. Blotters are dipped in water and hung up until excess water has stopped dripping from them. One hundred washed and dried seeds are placed on each blotter, another blotter laid loosely over them, and the whole placed in the incubator. Counts are made at the end of 3, 7, and 14 days.

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[1]General Chemist, Utah-Idaho Sugar Company.

[2]Italic numbers in parentheses refer to literature cited.

Sheared Seed

If the sample is large it is split in the riffle sampler used on whole seed until about 1 quart remains. This is further split in a small riffle sampler (5/16-inch riffles) until 100+1 to 5 seeds remain. One hundred seedballs are counted out, placed in the basket and washed for 2 hours. As with whole seed, the baskets are removed from the washer to a towel and the seeds allowed to dry. Each blotter is dipped in water and after dripping dry is placed on a small press. The press consists of two flat pieces of wood 5 inches by 6 inches hinged on the 6-inch side like the leaves of a book. On the inside surface of one of the leaves are 50 equally spaced upholsterer's tacks about ¼-inch in diameter and ⅛-inch high. On the inside of the other leaf at points directly opposite each tack is a countersunk hole about 5/16-inch in diameter and ⅛-inch deep. One end of the wet blotter is placed between the leaves and pressure applied. This molds 50 depressions on one half of the blotter. One washed and dried seedball is placed in each of these depressions, the other half of the blotter is folded over to cover them, and the whole is placed in the incubator for 10 days. Counts are ordinarily taken on the third, sixth, and tenth days.

Ninety percent of our sheared seed is sized 7/64-inch to 9/64-inch. With seed of this size it is extremely rare that a seedball with triple sprouts is encountered. Therefore the normal double sprouts are discarded at each count. Also it is easy to determine by inspection whether a normal single might produce an additional sprout upon further germination. If this appears probable the normal single is saved for the full 10 days. Otherwise the normal singles are discarded at each count. Those seeds which germinate abnormally or about which there is a question are left on the blotter for the full 10 days. A seedball which germinates one sprout abnormally and one normal radicle is counted as a normal single.

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PLANT PATHOLOGY AND ENTOMOLOGY

Movements of Spring-Generation Beet Leafhoppers Into Beet Fields of South-Central Idaho[1]

J. R. Douglass, H. C. Hallock, D. E. Fox, and R. N. Hofmaster[2]

Questions repeatedly asked about the spring movement of the beet leafhopper (*Eutettix tenellus* (Bak.)), the vector of the virus of curly top disease, from its spring-breeding host plants in the desert to the beet fields are: (1) When does the movement start? (2) How long is the period of movement? (3) What is its magnitude? (4) At what time of the season do leafhoppers enter the cultivated fields?

In an endeavor to answer these questions the study of the movement of the beet leafhopper into cultivated fields was begun several years ago in south-central Iraho. Annand *et al.* (*1*)[3] delt with the movements in 1930 and pointed out that the flight was not completed in a few days but was continuous. Hills (*9*) studied the movement of the spring generation in the central Columbia River breeding area for 1931-33 and concluded: "The leafhopper usually disperses from this breeding area between May 20 and June 30, movements being more or less continuous during this period." Douglass *et al.* (*4*), working in southern Idaho, compared the spring movement of the leafhoppers into untreated experimental plots with the movement into commercial fields in 1937, and later (*5*) discussed the movements into cultivated fields in this area and in northern Utah during the seasons of 1940 and 1941. Fox *et al.* (*6*) presented similar data for the period 1930-37, giving dates of initial movements, populations at intervals and at the peak, and the date on which the peak was reached. Movements of the beet leafhopper in southern Idaho are from local spring breeding areas and do not involve long-distance movements.

Small sugar beet plants are more susceptible to injury by curly top than are the larger plants. This holds true even for curly-top-resistant varieties, although they are less subject to injury than European varieties formerly grown (Giddings, 7). Hence the magnitude and

[1]This work was carried out in general cooperation with the Bureau of Plant Industry, Soils, and Agricultural Engineering of the U. S. Department of Agriculture, the Idaho Agricultural Experiment Station, and the Idaho Crop Pest Commission of the State of Idaho.

[2]Bureau of Entomolgy and Plant Quarantine, Agricultural Research Administration, U. S. Department of Agriculture. Resignation of Fox effective May 22, 1945. M. W. Allen, M. F. Bowen, F. K. Bracken, A. L. Burroughs, B. F. Coon, J. D. DeCoursey, J. A. Gillett, F. H. Harries, C. F. Henderson, G. M. Hess, Jr., A. O. Larson, H. M. Mason, W. Owen, and W. E. Peay assisted in obtaining the field notes

[3]Italic numbers in parentheses refer to literature cited.

time of the spring movement of the leafhopper into beet fields are important factors in determining the extent of curly top epidemics. If the lessened injury to older plants and the wide-spread use of curly-top-resistant varieties are taken into account, large populations of the summer generations, which enter the beet fields later in the season, may be relatively unimportant.

Life History of the Beet Leafhopper.—In southern Idaho the beet leafhoppers pass the winter in the adult stage. Females are fertilized in the fall and live until spring, but males die during the winter. Egg laying normally begins in March, and adults of the first, or spring, generation appear in May or June. The adults of the second, or summer, generation appear in July and the early part of August, and those of the third, or overwintering, generation in September or October. There is considerable overlapping of generations, especially during the summer and early in the fall. The sequence of host plants required for the development of this insect has been discussed by Carter (*2*), Cook (*3*), and Piemeisel and Chamberlin (*10*).

Methods of Investigation.—In order to determine the time and magnitude of the spring-generation movement of the beet leafhoppers into the cultivated area, six sugar beet fields on the western edge of the Twin Falls irrigated tract near Buhl and Castleford, Idaho, were selected for study each year from 1935 to 1944, inclusive. These fields were chosen because they are close to the spring breeding grounds that lie to the west of the cultivated area. The density of the leafhopper population decreases as the distance from the breeding grounds increases. In general the beet leafhopper moves with the wind, but occasionally, when the velocity is very low, the insect travels against the wind. Since the prevailing wind direction in the spring over the Snake River Plains is from the west, the movement is from the breeding grounds eastward up the Snake River Valley. The tributary breeding grounds being warmer than the local areas, the spring immigrants begin to move into the beet fields before the local insects mature.

Leafhopper populations were determined by the method described by Hills (*8*), with the use of Hills' sampler, which traps the insects in circular areas containing 1 square foot. In unthinned fields the sampling areas were located at random on the rows of beet plants, but in thinned fields the sampler was placed over random plants. In practice, beet plants are usually thinned to about one plant per foot of row. A total of 100 sampling areas were examined in each field, except in heavily infested fields, where smaller members were used.

Most of the studies were begun in the first half of May but all of them several days in advance of the anticipated appearance of the

incoming spring leafhoppers, and they were continued until after the peak of infestation was reached. During most seasons the fields were examined every 2 or 3 days, but occasionally weather conditions interfered and the intervals between examinations were longer.

The appearance of males in the beet fields is an excellent criterion of the start of the spring movement, and since 1937 it has been used in these studies to mark the beginning of the movement. Females cannot be used satisfactorily for this purpose, because when the weather is cool during the latter part of the nymphal period, dark-colored forms similar to overwintered individuals are produced.

To determine how long overwintered females were present in beet fields, all beet leafhoppers collected in 1939 were brought to the laboratory for examination. The overwintered forms were distinguished from the spring generation by their coloration, as described by Severin (*11*), and by general appearance. The peak of overwintered population was recorded on May 3, and was followed by a gradual decrease. In 1939 overwintered females were present in beet fields from April 17 to June 21, or over a period of 65 days. April 2 was the earliest date that overwintered females were found in beet fields during the 10-year period.

The term "winter annuals" in this paper refers to weeds, chiefly mustards. The more important are flixweed (*Descurainia sophia* (L.) Prantl), green tansymustard (*D. pinnata* spp. *filipes* (A. Gray) Detling), perfoliate peppergrass (*Lepidium perfoliatum* L.), and tumblemustard (*Sisymbrium altissium* L.). Under favorable conditions the seeds of these weeds usually germinate in the fall. The young plants develop small rosettes of leaves, remain alive throughout the winter, and complete their growth the following spring.

Spring Movement.—Some beet leafhoppers overwinter on winter annuals found growing in patches along canal banks, fence rows, railroads, roadsides, in fields and overgrazed pastures, and on idle, reverted, and waste lands within and adjoining the cultivated areas. The spring generation develops on weed host plants in the breeding areas, and then the adults disperse to summer hosts; therefore, the progress of this movement coincides with the maturation of the insect. Charts were prepared to illustrate this movement into beet fields each spring during the period of study. The charts for 1935, 1937, 1938, 1940, and 1941 are presented in this paper. The populations in the other years were low, and charts are not shown for them, since the spring movement followed the same general pattern as in 1940.

There were a few beet leafhoppers in the fields when the first samples were taken in May of the years 1935, 1937, 1940, and 1941.

These were overwintered females that had moved into the sugar beet fields, either from weed-host patches nearby or from the desert breeding grounds, soon after the beet plants appeared above ground. The highest population of overwintered females found during the period of this study was recorded in June 1938.

Wallace and Murphy (*12*) have shown that overwintered beet leafhoppers are very important in starting new curly top infection centers. The overwintered viruliferous females infect a small percentage of the plants throughout the fields, from which the virus is spread to other plants by the incoming spring generation.

Table 1 shows the dates of the initial spring movement, the dates on which the highest populations were recorded, the period between each initial movement and its peak, and the density of the leafhopper populations for the 10-year period.

It is impossible to determine the period between the peak and the end of the spring movement, since there is no practical method of distinguishing incoming leafhoppers from those already there and from those that develop from eggs deposited in beets by overwintered females. The decrease in population after the peak is reached is due to a redistribution of the leafhoppers and to natural mortality. It is safe to assume that this period extends over 2 to 3 weeks, depending on the season. The magnitude and rate of movement may also vary, depending on the cardinal factors governing the reproduction, maturation, and activity of the leafhopper. These factors are host-plant conditions, temperature, moisture, and, during movement, other weather conditions.

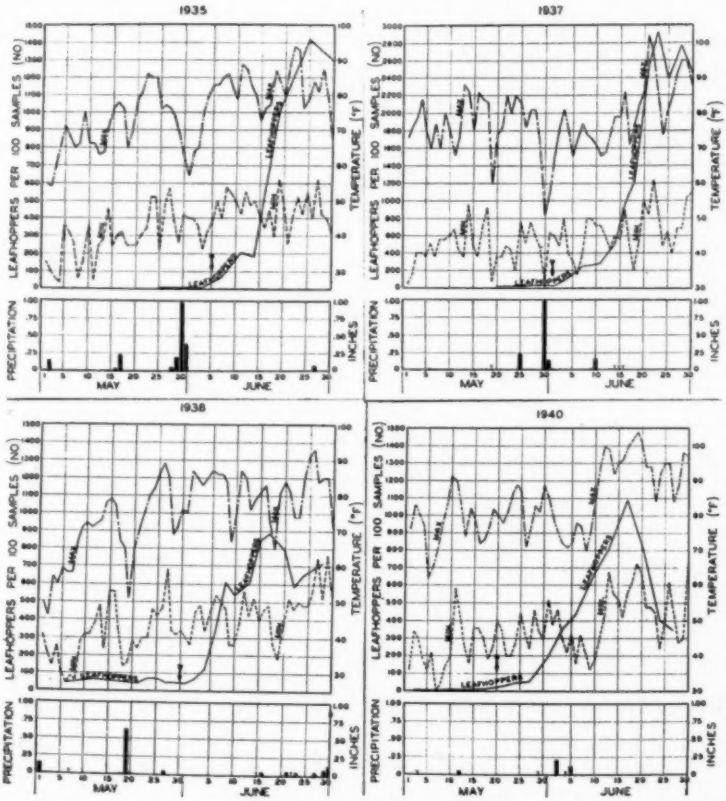
Table 1.—Beet leafhopper movements into six representative beet fields of the Buhl-Castleford area during the seasons of 1935-44.

Year	Date of spring movement		Time required to reach peak	Average population per 100 samples at peak
	Initial	Peak		
			Days	Number
1935	June 5	June 25	20	1,416
1936	May 25	June 29	35	232
1937	June 2	June 23	21	2,939
1938	May 30	June 17	18	880
1939	May 17	June 14	28	85
1940	May 20	June 17	28	1,089
1941	May 12	June 13	32	1,496
1942	June 1	June 29	28	169
1943	May 26	July 7	42	79
1944	May 15	July 10	56	270
Average	May 25	June 24	31	866

Discussion

The chart for 1935 shows that in that year a few beet leafhoppers were in the fields in May before the spring movement began. These were the overwintered females discussed earlier in this article. Each year the population in the fields remained low for a few days after the movement of the spring generation began, and then the rate of movement gradually increased until the peak of population was reached. After the peak was reached the rate of movement decreased gradually.

Meteorological conditions affect the flight activity of the beet leafhopper. From information at hand the writers have attempted to determine what some of these conditions are. The infestation curve



Spring movement of beet leafhoppers into beet fields as related to the temperature and precipitation, Buhl and Castleford, Idaho. Arrows point to the dates the first spring-generation leafhoppers appeared in the fields.

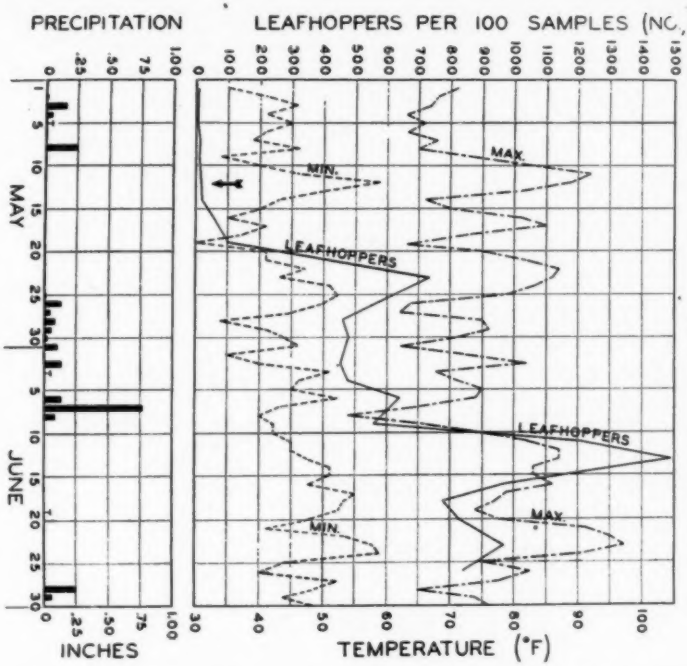
for 1935 is not always smooth, and at intervals decreases in population were recorded. These decreases are readily understood, because cool, cloudy, rainy, and windy weather affects the activity of this leafhopper and may also affect the accuracy of the counts. During adverse weather leafhoppers hide under clods and trash and between beet-leaf petioles, where they are often overlooked. Population counts are often made in fields that are being cultivated, but such counts are less satisfactory than those made in areas that are not being disturbed. Observations have shown that during light sprinkles of rain in warm weather the leafhoppers are not confined to the beet plants but are found scattered throughout the field.

Unfavorable weather affects not only the accuracy of the population counts but also the movement of the leafhopper from the breeding grounds into the cultivated area. A good example is presented in the chart for 1941. The spring movement started on May 12 in that year. There was a gradual increase in the rate of movement until May 23, when an average of 734 leafhoppers per 100 samples was recorded. The population decreased during the period of rainy weather and low temperature from May 24 to June 3. No precipitation occurred on June 4 and 5 and a slight increase in population was recorded on June 6. After further precipitation on June 6, 7, and 8 the population again was reduced on June 9. This rainy period evidently caused some mortality of leafhoppers in beet fields and was distinctly unfavorable for movements of the insects. During this period an accumulation of adult leafhoppers was noted on spring hosts in the breeding grounds, which is a rare occurrence. Immediately following the period of inclement weather the population increased to the peak on June 13.

The charts show a tendency for the population to decrease when the maximum temperature for the day was 74° F. or below. In some years there were exceptions, but it appears that counts were not made on those days. This tendency indicates that leafhopper flights took place on days when the maximum temperature was above 75°, but this is not the minimum threshold of flight[4].

The population curves show that during the periods when spring-generation leafhoppers are moving there are times when the rate of movement is great. The curves also show that some of the movements were continuous for several days, as from June 14 to 23, 1937, when 83 percent of the incoming leafhoppers moved into the cultivated area in 9 days. There were also heavy flights of short duration, such as occurred from June 4 to 8, 1938, and from June 9 to 11, 1941, when 52 and 44 percent of the incoming leafhoppers entered the fields

[4]F. R. Lawson, J. C. Chamberlain, and G. York. Unpublished manuscript.



Spring movement of beet leafhoppers into beet fields as related to the temperature and precipitation, Buhl and Castleford, Idaho. Arrows point to the dates the first spring-generation leafhoppers appeared in the fields.

in 4 and 2 days, respectively. During years of comparatively high populations most of the incoming leafhoppers entered the beet fields during periods of intensive movement. In 1935, 1937, 1940, and 1941 most of the leafhoppers entered the fields during continuous movements extending over several days, and during these continuous movements there were periods when the rate was more intensive than at other times. For example, in 1935 during the 5-day period June 15 to 19, 58 percent of the leafhoppers entered the fields, as compared with 29 percent for the 6-day period immediately following, and in 1937 during the 3-day period June 19 to 21, 45 percent of the leafhoppers entered the fields, as compared with 25 percent during the preceding 4-day period, and 13 percent for the 2-day period immediately following the period of intensive movement.

Data on wind direction and velocity, obtained by means of self-recording instruments located at Twin Falls, were studied during the periods of intensive leafhopper movements. The prevailing wind during these periods was from the west and the northwest. No correlation

was shown between the velocity of the wind and the leafhopper movements, because population counts were not made often enough.

Summary

Questions repeatedly asked about the spring movement of the beet leafhopper, the vector of the virus of curly top disease, from its spring-breeding host plants in the desert to the beet fields are: (1) When does the movement start? (2) How long is the period of movement? (3) What is its magnitude? (4) At what time of the season do leafhoppers enter the cultivated fields? In an endeavor to answer these questions the study of the movement of the beet leafhopper into cultivated fields was begun several years ago in south-central Idaho. Various authors have published on the movement in different years.

Leafhopper populations were determined with the use of the Hills' sampler, which traps the insects in a circular area containing 1 square foot. Both unthinned and thinned beet fields were sampled, the samples being taken at random.

Upon reaching maturity adult beet leafhoppers of the spring generation disperse to their summer hosts, and the progress of this movement coincides with the maturation of the insect. The date of the initial spring movements in southern Idaho has ranged from May 12 to June 5, with May 25 as the average for the 1935-44 period. The date for the peak of movement has ranged from June 13 to July 10, with June 24 as the average. The period between the initial movement and its peak has ranged from 18 to 56 days, with 31 days as the average. The magnitude of the population at its peak has ranged from 79 adults per 100 square feet in 1939 to 2,939 in 1937, with an average of 866, or 8.7 leafhoppers per beet. Adverse meteorological conditions affect flight after the movement has started and also affect the accuracy of population counts.

Leafhopper flights took place on days when the temperature was above 75° F., but this is not the minimum threshold of flight.

Most of the incoming beet leafhoppers entered the cultivated areas during continuous movements over a period of several days or during heavy flights of short duration. During these continuous movements there were times when the rate was higher than at other times.

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Lygus Control in Sugar Beets Grown For Seed

ORIN A. HILLS, K. B. MCKINNEY, and WALTER E. PEAY[1]

Studies to determine the presence and effect of insects, other than the leafhopper, on the sugar beet seed crop were first undertaken by the Bureau of Entomology and Plant Quarantine at Phoenix, Ariz., in 1938. The beet leafhopper (*Eutettix tenellus*) (Bak.)) as a vector of the curly top disease was known to be of considerable importance in the growing of this crop, and a method of controlling this insect had already been developed by Romney (*10*).[2] This insect damages seed beets primarily in the fall of the year while they are still in the vegetative stage. Insect population studies from 1938 to 1945 showed that, of the insects in the seed-beet fields in the spring, *Lygus* sp. and the Say stinkbug (*Chlorochroa sayi* Stal) were causing the most damage, and that lygus was of greater concern because of its general occurrence each year. The Say stinkbug, although capable of doing much damage to the crop, only occasionally becomes numerous that the primary damage caused by these insects was a reduction in enough to be of economic importance. These studies further showed the percentage of viable seed produced, although they also had a tendency to reduce the yield of seed (*1, 3, 4, 5*).

Experiments leading to the development of a method for controlling these insects have been under way since 1940. Since the work was started, beet field populations of the Say stinkbug have been too low for experimental work; therefore, experiments have dealt almost entirely with the lygus bugs—the tarnished plant bug, *L. oblineatus* (Say), the western plant bug, *L. hesperus* Knight, and the pale plant bug, *L. elisus* Van D. Progress reports summarizing the results of these experiments on small-scale field plots have been issued from time to time (*6, 7, 8*).

Laboratory Tests

Approximately 116 materials or combinations of materials were

[1]Bureau of Entomology and Plant Quarantine, Agricultural Research Administration, U. S. Department of Agriculture. The authors acknowledge the cooperation and assistance of the Western Seed Production Corporation, the West Coast Beet Seed Company, and the Farrar-Loomis Seed Company in carrying on the large-scale lygus control experiments in seed-beet fields in Arizona, New Mexico, California, and Oregon. The authors also acknowledge the assistance of J. C. Chamberlin and Mervin Nielson, of the Bureau of Entomology and Plant Quarantine, Don C. Mote, of Oregon State College, and of the personnel of the seed department of the Utah-Idaho Sugar Company. The work in Utah was done in cooperation with the Utah Agricultural Experiment Station.

[2]Italic numbers in parentheses refer to literature cited.

tested in the laboratory to determine their comparative toxicity to lygus bugs and the Say stinkbug. Many of them were new materials, the insecticidal value of which had not been established. The results have been recently published (Hills and McKinney *9*). Materials showing promise were later tested in small field plots to determine not only their effectiveness against these insects but also their effect, if any, on the plant and seed crop. Usually materials that showed promise against these insects in laboratory cages showed some value in field tests, but some of them proved to be too caustic to use on the plants.

Small-Plot Tests

Small-plot tests to compare values of various insecticides in controlling lygus on sugar beets grown for seed have been conducted in the Salt River Valley of Arizona from 1940 to the present time.[3] Each year from 42 to 64 plots approximately 1/50 of an acre in size and arranged in either a Latin square or randomized blocks were used, and data regarding insect populations, seed yield, and viability were obtained. A curly top resistant variety was used each year until 1945 in order to prevent complications due to possible curly top infection in the fall. This was one of the earliest bolting and most vigorous varieties. The 1945 plots included also one of the later bolting and less vigorous varieties. These plots were arranged in a split plot, randomized block design in which the varieties were replicated three times in major blocks. Each of the six variety plots was divided into smaller plots in which the insecticidal treatments were tested. The insecticide tests were replicated six times.

Each year the plots were laid out with 9- or 10-foot roadways between plots in one direction and at least 6-foot spaces between plots in the other direction. This arrangement facilitated insecticide applications and insect population sampling. The tall, dense growth of the beet seed plants in the spring presented difficulties in this regard. During 1940, 1941, and 1942 the insecticides were applied by means of hand dusters or an especially designed power sprayer (*2*) operated from two towers mounted on runners with a footbridge between, of sufficient length to span the plots. These towers were drawn by automobiles along the roadways between the plots. Cloth-covered, wooden framework barriers were set up around the plots to prevent drift of the insecticides. In 1943 and 1944 a more simple technique was employed, which consisted in dusting a plot simultaneously with hand dusters from two platforms built on the tops of cars as illustrated in figure 1. This method was adopted primarily to save time

[3] In this area sugar beets for seed are planted in August and September and harvested the following June or July. Plots are referred to according to the calendar year in which the crop is harvested.

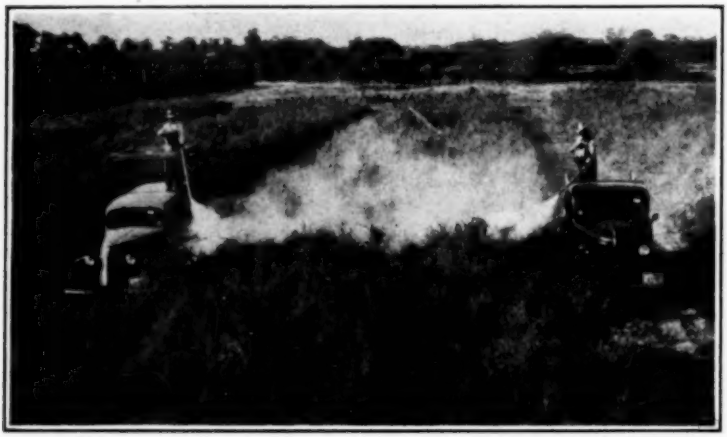

Figure 1.—Applying insecticides from car-top platforms to small plots of seed beets for experimental control of lygus. Phoenix, Ariz., 1943.

and labor but had the disadvantage of uncontrolled insecticide drift between the plots at the time of application. In 1944 a springboard type of scaffold attached to a pickup truck, developed for taking insect population samples, was adapted for use in the application of the insecticides (figure 2).

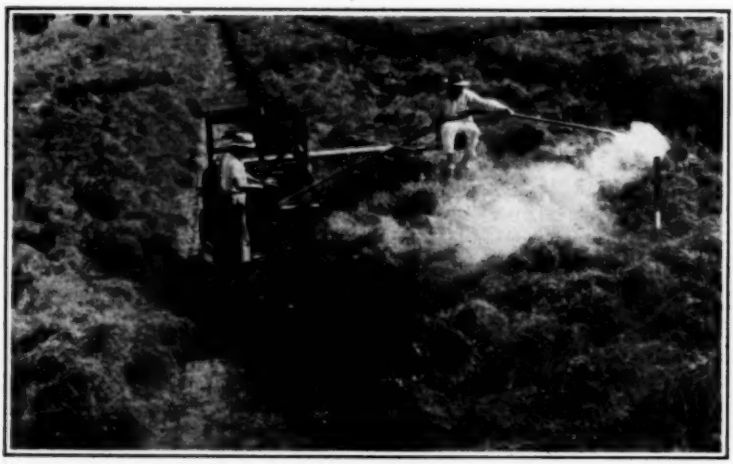

Figure 2.—Applying insecticides from the springboard scaffold to small plots of seed beets for experimental control of lygus. Phoenix, Ariz., 1945.

Figure 3.—Taking insect population samples in experimental plots of seed beets by means of the sweep net from the springboard scaffold. Phoenix, Ariz., 1944.

During 1940, 1941, and 1942 various methods were tried to obtain adequate insect population samples. While these methods gave comparative results between treatments, the data are not directly comparable with data of later years and will therefore not be presented. During 1943, 1944, and 1945 the sweep-net method of sampling was adopted. One disadvantage of this method is the difficulty of getting through the field after the seedstalks have become entangled. With the development of the springboard type scaffold the sweep-net operator was carried over the tops of the plants (figure 3).

All the seed from the 1940, 1941, and 1942 plots was harvested, threshed and cleaned in order to obtain yield data. Samples of seed for germination analyses were taken from the harvested seed from each plot. In 1943, 1944, and 1945 only a sample area four rows wide and 10 feet long from the center of each plot was harvested. Yields were based on the weight of seed from these areas, and samples of seed for germination were taken. This technique has saved much time and labor in harvesting and handling the seed.

In 1940 and 1941 lygus populations in the Salt River Valley were low, and populations were correspondingly low in the experimental plots. Seed viability, as indicated by the germination tests in the untreated check plots, was above 80 percent in both years and, although some increase in the percentage of viable seed was indicated for the more effective insecticides, the results were not outstanding.

From 1942 to 1945 radishes were planted in the roadways between the plots to increase the numbers of lygus and to insure adequate popu-

lations on which to make insecticide tests. The radishes were planted in the fall at about the same time the beets were planted, but they bloomed and matured considerably ahead of the beets. Lygus bugs were introduced onto the radishes in the fall and sometimes also in the spring. These insects seem to prefer tender, developing flower buds or immature seed for breeding, and a brood of lygus was developed on these radishes at about the time the beets were beginning to bolt. When the radishes were cut, the insects were forced onto the

Figure 4.—Experimental seed beet plots on April 6. Radishes in roadways are in seed stage and serve as breeding host for lygus; beets are just beginning to bolt. Phoenix, Ariz., 1942.

beets. Figure 4 shows the radishes blooming and setting seed in the roadways between the plots. Just how much this technique increases the number of lygus bugs in the plots is not definitely known, but from 1942 to 1945 populations in the plots were sufficiently high for satisfactory insecticide tests, although they were very low in 1944 in the commercial seed beet fields.

In 1942 seven insecticides were tested in eight replicate plots arranged in a Latin square. Five applications of all materials were made at weekly intervals during May at an average rate of approximtely 90 pound per acre. Seed yield and viability data from these experiments, which are given in table 1, indicate that the best results were obtained with a pyrethrum extract dust, either with or without sulphur. Dusting sulphur also gave good results, but the addition

Table 1.—Yield and viability of seed from small plots of seed beets dusted five times at weekly intervals for lygus control (8 replicate plots in a Latin square). Phoenix, Ariz., 1942.

Treatment (Amounts in percent)	Seed yield, pounds per plot (1/58 acre)	Seed viability, percent
Pyrethrum concentrate* 10 (pyrethrins 0.2), pyrophyllite 40, sulphur 50	70.6	90.1
Pyrethrum concentrate* 10 (pyrethrins 0.2), pyrophyllite 90	74.7	89.3
Sulphur	66.2	84.8
Phthalonitrile 13.3, sulphur 86.7	64.0	84.7
Dinitro-o-cyclohexylphenol 1, sulphur 50†	68.3	84.0
Paris green 7.5, sulphur 92.5	65.7	83.7
Dinitro-o-cyclohexylphenol 1†	64.1	75.1
Untreated check	60.8	61.1
Difference required for significance (P = 0.05)	5.0	4.7

*Proprietary dust mixture prepared from pyrethrum extract.
†Proprietary mixture, inert diluent unknown.

of phthalonitrile, dinitro-o-cyclohexylphenol, or paris green to the sulphur did not increase its effectiveness.

In 1943 five insecticides were tested in eight replicate plots arranged in randomized blocks. Three applications of all insecticides except the pyrethrum-sulphur dust, at approximately 80 pounds per acre-application, were made at 10-day intervals from April 30 to May 20. Previous experiments had shown two applications of this material to be effective in controlling lygus.

Lygus populations for each of these treatments are shown in figure 5. These data indicate that all treatments reduced lygus populations, and that the two applications of pyrethrum-sulphur dust were more effective than three applications of any of the other materials. No differences were indicated for the yellow or black sulphurs; both were shown to be superior to either the phenoxathiin-sulphur or sulphur-arsenical dust.

The seed from the 1943 plots were separated according to size at the time of cleaning. All seed retained by an 8/64- by 3/4-inch screen were termed "large seed," while the seed passing through this screen but retained by a 7/64- by 3/4-inch screen were classed as "small seed." Yield data and results of analyses for both large and small seed are given in table 2. There were no appreciable differences in seed yield. In general the viability of seed was higher in the plots having the lower lygus populations. Two applications of the pyrethrum-sulphur dust were more effective in increasing the seed viability than three applications of the other materials.

From the data in table 2 it is easily determined that slightly more than 15 percent of the total yield consisted of small seed. It is

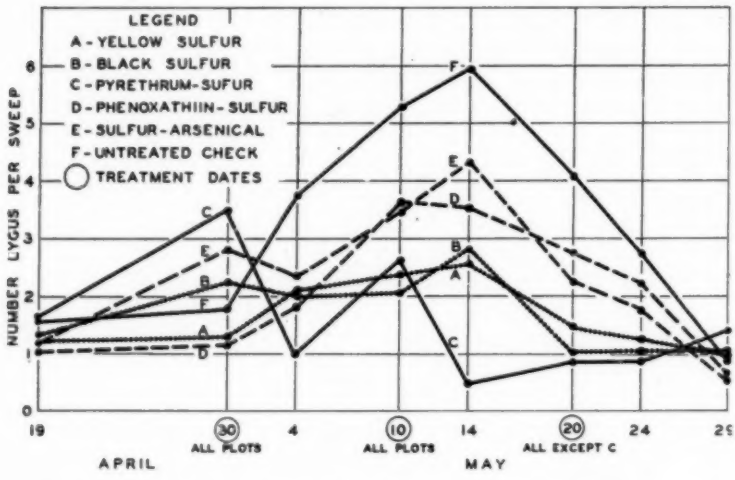

Figure 5.—Lygus populations as indicated by the sweep net in variously treated plots of seed beets. Phoenix, Ariz., 1943.

generally understood that the percentage of germinating seed is lower in case of small seed, and the data in the table substantiate this theory. However, these data also show that where lygus bugs were controlled

Table 2.—Yield and viability of seed from small plots of seed beets dusted three times at 10-day intervals for lygus control (8 replicate plots arranged in randomized block). Phoenix, Ariz., 1943.

Treatment (Amounts in percent)	Seed yield, ounces per plot (8- by 10-foot sample area)		Seed viability, percent		
	Large	Small	Large	Small	Total*
Pyrethrum concentrate† 10 (pyrethrins 0.2), pyrophyllite 40, sulphur 50	68.1	14.3	88.1	63.4	83.7
Sulfur	68.6	12.6	85.8	58.6	81.5
Black (gashouse) sulphur	65.1	12.3	83.9	58.9	19.9
Phenoxathiin 15, sulphur 60, diatomaceous earth 25	69.8	11.7	82.9	53.3	78.6
Calcium arsenate 7.9, calcium arsenite 0.7, sulphur 87.5‡	59.6	11.0	81.3	56.1	76.3
Untreated check	61.7	11.4	78.4	45.8	72.3
Difference required for significance (P = 0.05)	**	**	4.0	5.9	----

*Figures in this column represent percentage of germinating seed that would have resulted if all seed had been cleaned over a 7/64- by 3/4-inch screen.

†Proprietary dust mixture prepared from pyrethrum extract.

‡Proprietary mixture, inert diluent unknown.

**Not significant by the F test.

the viability of the small seed as well as the large seed was improved, and furthermore that the increase in the percentage of viable seed due to lygus control was greater with the small seed.

In 1944 seven insecticides were tested in eight replicate plots arranged in a Latin square. They were applied at an average rate of 100 pounds per acre per application. Two applications were planned for all materials, on May 11 and 19. However, one application of DDT had reduced lygus numbers so greatly that a second application of this insecticide was considered unnecessary, and since one application of dinitro-o-cresol caused severe burning of the foliage, a second application was not made. Lygus populations obtained in 1944 are given in figure 6. Likewise, as shown in table 3, a single application of DDT increased the viability of the seed at least as much as two applications of other materials.

Approximately 13 percent of the total seed obtained from the 1944 plots was small seed, and the data in table 3 indicate, as did the 1943 data, that the viability of the small seed was improved to a greater degree by lygus control than was the viability of the large seed.

In the 1945 experiments the two varieties of beets planted in split plots, arranged in randomized blocks, gave opportunity for testing the effectiveness of lygus control on other than the vigorous early bolting variety used in experiments of previous years. The results of the treatments were compared in three replicate plots on each variety, or a total of six replicates for each insecticide treatment. Except for the three-application treatment of DDT made on April

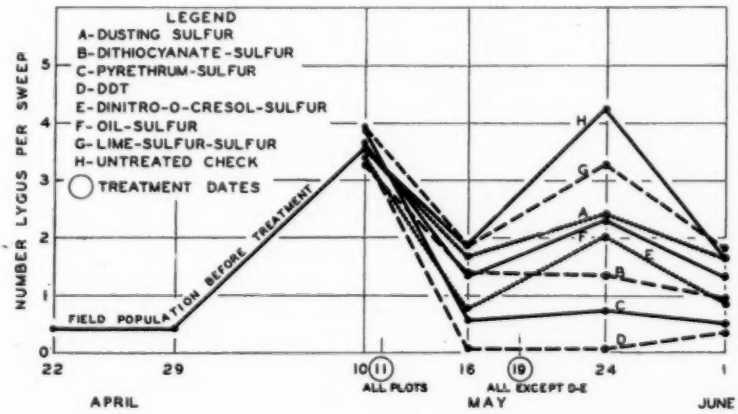

Figure 6.—Lygus populations as indicated by the sweep net in variously treated plots of seed beets. Phoenix, Ariz., 1944.

Table 3.—Yield and viability of seed from small plots of seed beets dusted experimentally for lygus control (8 replicate plots arranged in a Latin square). Phoenix, Ariz., 1944.

Treatment (Amounts in percent)	Number of applications	Seed yield, per plot (8- by 10-foot sample area)		Seed viability, percent		
		Large	Small	Large	Small	Total*
DDT 4.5, pyrophyllite 95.5	1	102.4	15.9	93.0	79.2	91.2
Pyrethrum concentrate† 10 (pyrethrins 0.2), pyrophyllite 40, sulphur 50	2	90.3	13.3	90.6	75.4	88.6
'Beta, beta'-dithiocyanodiethyl ether 3.25, sulphur 75‡	2	88.0	13.5	86.4	70.0	84.2
Dinitro-o-cresol 1, sulphur 99	1	68.9	10.7	84.6	59.0	81.1
Sulfur	2	90.0	14.0	82.9	55.4	79.1
Lime-sulfur 20, sulphur 80	2	91.3	13.0	82.7	54.7	79.2
Petroleum oil 5, sulphur 57, talc 38	2	96.5	13.6	82.5	54.8	79.1
Untreated check	0	94.6	11.9	73.1	39.2	64.9
Difference required for significance (P = 0.05)		13.1	2.0	3.6	7.0	.... ..

*See footnote 1, table 2.

†Proprietary dust mixture prepared from pyrethrum extract.

‡Proprietary mixture, inert diluent unknown.

18 and 27 and May 9, the first application of each insecticide treatment was made on May 9 and the second on May 21. The improved dusting technique used in 1945 (figure 2) permitted a more even application of insecticides, and the average rate was cut to approximately 48 pounds per acre-application.

The effectiveness of each treatment as indicated by lygus populations is shown in figure 7. These data indicate that all treatments reduced lygus populations; they also show considerable differences in the effectiveness of the various treatments. One application of 5-percent DDT-pyrophyllite was better than two applications of the pyrethrum-sulphur dust. Three applications of 5-percent DDT dust held populations at a very low level during the entire season, but after May 14 populations in these plots were not different from those in plots receiving only one application of DDT. The trends in the plots receiving one and two applications of sabadilla indicated that this material was not so effective as either the DDT or the pyrethrum-sulphur dust, and had very little, if any, residual effect. The dithiocyanate dust was also inferior to both pyrethrum-sulphur and DDT. Lygus populations in the untreated check plots did not show the decline after treatment in 1945 that they did in 1944 (figures 6 and 7). This was undoubtedly due to the prevention of insecticide drift during application.

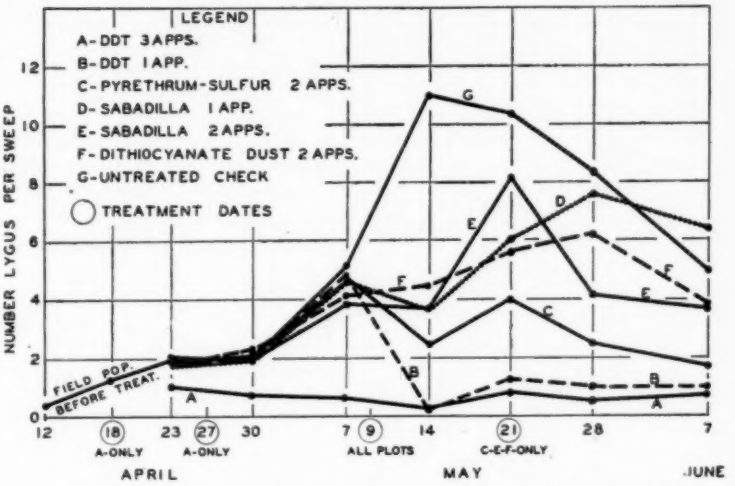

Figure 7.—Lygus populations as indicated by the sweep net in variously treated plots of seed beets. Phoenix, Ariz., 1945.

The seed-cleaning operation was the same in 1945 as in the two previous years, the large and small seed being separated. Yield data from the 1945 plots, irrespective of varieties, are given in table 4 and show significant increases in yield of large seed for all treatments except the dithiocyanate dust and one application of sabadilla. Significant increases in yield of small seed are indicated for all treatments

Table 4.—Yield and viability of seed from small plots of seed beets dusted experimentally for lygus control (6 replicate plots arranged in randomized block). Phoenix, Ariz., 1945.

Treatment (Amounts in percent)	Number of applications	Seed yields, per plot (8- by 10-foot sample area)		Seed viability, percent		
		Large	Small	Large	Small	Total*
DDT 5, pyrophyllite 95	3	113.6	15.0	88.0	74.4	86.4
DDT 5, pyrophyllite 95	1	102.6	14.8	81.9	65.2	79.8
Pyrethrum concentrate* 10 (pyrethrins 0.2), pyrophyllite 40, sulfur 50	2	113.0	16.1	81.1	61.0	78.6
Sabadilla 10, pyrophyllite 50†	2	107.3	11.8	71.6	36.4	68.1
Sabadilla 10, pyrophyllite 50†	1	88.6	10.6	62.0	27.8	58.3
'Beta, beta'-dithiocyanodiethyl ether 3.5, sulphur 75†	2	94.6	11.8	60.2	30.1	56.9
Untreated check	0	83.0	10.0	45.8	15.6	42.5
Difference required for significance (P = 0.05)		13.9	1.8	9.8	9.5	— —

†Proprietary dust mixture prepared from pyrethrum extract.
‡Proprietary mixture, inert diluent unknown.

except the one application of sabadilla. Results of germination tests, also given in table 4, show that one application of a 5-percent DDT dust gave results as good as two applications of the pyrethrum-sulphur dust; they also show that one application of the 5-percent DDT dust applied on May 9 gave almost as good results as three applications. These data further show that, while some benefit was derived from the sabadilla and the dithiocyanate dusts, these materials were inferior to DDT and pyrethrum-sulphur dusts. Greater increases in seed yield and viability due to lygus control were shown in 1945 than in any of the previous years; this is probably due to higher lygus populations in the 1945 plots as well as better control. Greater increases in viability were again shown for small seed than for large. The mean yield of small seed from all plots in 1945 composed approximately 11 percent of the total yield.

Analyses of the data from the 1945 plots indicate, as is shown in table 5, that the lygus control program was equally effective on the two varieties, but that irrespective of insecticide treatment the more vigorous, early-bolting variety outyielded the less vigorous, late-bolting variety. There was also some tendency for the early bolting variety to produce a higher percentage of viable seed than the late-bolting variety, but these differences were not great enough to be mathematically significant.

Table 5.—Comparison of yield and viability of seed from two varieties of seed beets grown in experimental plots. Phoenix, Ariz., 1945.

Variety	Seed yield, ounces per plot (8- by 10-foot sample area)		Seed viability, percent	
	Large	Small	Large	Small
Early bolting, vigorous	117.4	13.3	74.3	57.3
Late bolting, less vigorous	83.4	12.5	65.8	41.4
Difference required for significance (P = 0.05)	19.6	*	*	*

*Not significant by the F test.

Large-Scale Control Experiments

Large-scale experiments for the control of lygus in seed beets have been conducted in Arizona, New Mexico, southern California, northern California, Oregon, and Utah. Most of the applications have been by airplane, although ground equipment has been used exclusively in New Mexico and Utah. The results have usually indicated that where lygus bugs were controlled the viability of the seed was improved; however, sometimes the increases in seed viability were not so great as expected. Other factors also may contribute to the nonviability of the seed.

Klamath Falls, Ore., and Northern California.—The first large-scale control experiments against lygus in seed beets were conducted at Klamath Falls, Ore., in 1942. Prior to 1942 high lygus populations and crop failures were reported from the Klamath Falls and northern California beet seed producing areas. Lygus populations in seed beets at Klamath Falls in 1942 were high, and field tests were conducted to determine the effectiveness of the pyrethrum-sulphur dust shown to be effective against lygus in small-plot tests at Phoenix. Two applications were made during July with a tractor-mounted power duster at the rate of 25 pounds of dust per acre-application. The first application was made when the plants were in the early bloom stage and the second application about 2 weeks later. This treatment resulted in good control of lygus and definite increases in the percentage of viable seed produced. Germination analyses by a commercial seed analyst showed 70.8 percent of viable seed from the treated portion of the field as compared with 49.5 percent from the untreated portion.

In 1943 the seed beets at Klamath Falls were frozen out by extremely low winter temperatures. In 1944 high lygus populations again occurred and one application of pyrethrum-sulphur dust was made as a commercial control program. A satisfactory kill was reported, but no further applications were made, and seed viability was so low that the crop was not harvested. Much of the acreage in northern California in 1944 was also left unharvested because of extremely low quality seed.

The beet seed acreage at Klamath Falls in 1945 was confined to one field of approximately 160 acres. Lygus populations in this field the first part of July were extremely high, nearly 20 per sweep of an insect net. The beets at this time were in the late pre-bloom stage, and the entire field, except for a small strip along one side, was dusted by airplane with 5-percent DDT at approximately 30 pounds per acre. Populations were reduced practically to zero and remained so throughout the rest of the season. Lygus numbers in the untreated strip were also greatly reduced, probably by drift of the insecticide during application, so that little or no differences in seed viability occurred between the treated and untreated areas. The viability of the seed produced in 1945 at Klamath Falls was not satisfactory, however, and the seed was marketable only after drastic cleaning. Factors other than lygus also probably contributed to the nonviability of seed produced in this area.

Portions of seed beet fields in northern California and Medford, Ore., were dusted with DDT during the blooming period of the beets in 1945, and lygus populations were satisfactorily reduced. In all

these fields lygus control was accompanied by increases in seed viability, and usually seed with satisfactory germination was produced.

Salt River Valley, Ariz.—The first large-scale control experiments in the Salt River Valley, Ariz., were conducted in 1943. In that year all such experiments except one were with dusting sulphur. From three to five applications, ranging from 40 to 50 pounds per acre, were made by airplane to a number of fields containing moderate to high lygus populations. In five of these fields untreated check areas were left, and samples of seed from the treated and untreated portions of the fields were taken for germination analyses at harvest time.[4] The mean percentage of viable seed from the untreated portions of the fields was 51.6 as compared with 65.9 from the treated portions.

Another airplane-dusting experiment was set up on a 65-acre field of seed beets to compare the effectiveness of five applications of dusting sulphur with two applications of pyrethrum-sulphur followed by three applications of dusting sulphur. The sulphur was applied to 55 acres, the pyrethrum-sulphur to 5 acres, and 5 acres were left as an untreated check. Germination analyses showed that 76.6 percent of the seed from the area treated with pyrethrum-sulphur was viable, 68.5 percent from the sulphur-treated area, and only 44.6 percent from the untreated check.

In 1944 lygus populations in the Salt River Valley were low and the viability of the seed produced that year was correspondingly high; none of the fields were treated for lygus control.

In 1945, lygus populations in the seed beet fields of the Salt River Valley were high, and control was undertaken in practically every field. DDT was unavailable except for large-scale control experiments, and the pyrethrum-sulphur dust previously recommended was entirely unavailable because of wartime conditions. A new insecticide, sabadilla, was obtainable, and cage tests indicated that this insecticide was toxic to lygus, but no field tests on seed beets had been made. A few large-scale single applications by airplane early in the season gave fair results. Therefore single commercial applications

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[4]Unless otherwise mentioned, all samples of seed were taken by hand from the windrow or shocks and were threshed, cleaned, and placed between moist blotters for germination, according to the rules and recommendations for testing seed established by the U. S. Department of Agriculture (11). For cleaning these seed samples a 7/64- by 3/4-inch screen and only enough air to separate the light trash from the seed were used, so that virtually all seed were saved. Germination analyses were lower than would be obtained from the more drastic commercial cleaning of the seed, but more accurate data were obtained on the viability of the total seed produced regardless of weight or size.

of a 10-percent sabadilla dust were made to many of the fields in the vicinity of Phoenix. It was soon found, however, that, although approximately 75 percent mortality could be expected within 24 hours from the application of 40 pounds per acre of 10-percent sabadilla dust by airplane, this insecticide had little or no residual effect, and lygus populations soon again reached a high level in the dusted fields.

Additional supplies of DDT became available later in the season, and during the first 3 days in June many of the fields previously treated with the sabadilla dust were redusted with DDT. However, the beet seed crop at this time was approaching maturity and, although lygus populations were reduced, much of the damage had already been done and results from these applications were not nearly so good as those obtained by applications of DDT during the early bloom period of the plants. Several untreated portions of fields were left as checks, and lygus population samples and samples of seed for germination analyses were taken in these untreated areas as well as in the variously treated portions of fields. Seed germination data from eight fields, portions of which were variously treated for lygus control, are given in table 6. These data clearly show that a 4- or 5-percent DDT dust, applied at the rate of 30 to 40 pounds per acre May 16 or earlier, gave good results. This date of application corresponded to the early bloom or full bloom period of the plants. A 10-percent sabadilla dust applied at about the same time, and followed by a 5-percent DDT dust the first of June, increased the viability of the seed somewhat, but the value of the 10-percent sabadilla alone was questionable.

Table 6.—Percentage of viable seed from variously treated portions of seed beet fields, Salt River Valley, Ariz., 1945.

Field No.	4- or 5-percent DDT dust applied May 16 or earlier	10-percent sabadilla dust applied May 16 or earlier	10-percent sabadilla dust applied May 21 or earlier and 5-percent DDT dust applied June 2	Untreated check
1	87.4	----	----	47.5
2	69.1	----	----	42.4
3	75.3	40.9	66.5	----
4	80.8	37.5	59.2	----
5	70.7	----	----	51.5
6	87.1	----	----	73.2
7	88.8	----	73.2	56.9
8	92.5	53.0	70.0	49.8

Albuquerque, N. Mex.—The first large-scale control experiments at Albuquerque, N. Mex., were undertaken in 1943. The 1942 lygus populations were extremely high, and yields and viability of the seed produced that year were very low. A survey of the beet fields the middle of May 1943 indicated that the infestation was going to be

moderately heavy, and therefore a control program involving practically all fields in the area was outlined. Two applications of the pyrethrum-sulphur dust were recommended for the fields containing high populations, and either one application of pyrethrum-sulphur followed by two applications of sulphur, or three applications of sulphur alone, were recommended for the other fields. Applications were to be made with ground equipment at the rate of 25 to 30 pounds per acre, and several portions of fields were to be left untreated as checks.

Considerable difficulty was encountered in carrying out this program, and results in all cases were not so good as anticipated. Only one duster, a tractor-mounted power duster, was available, and since the fields were scattered over a wide area it was difficult to make the applications at the proper time in all fields. Moreover, there was considerable wind, which further delayed operations. Consequently, in most fields not more than two applications of any insecticide were made, and many fields received only one of pyrethrum-sulphur dust; often this application was not so timely as it should have been. The kill obtained with this equipment and the pyrethrum-sulphur dust was better than 95 percent at 24 hours. However, pyrethrum has very little residual effect, and populations built up somewhat after application. Where one portion of a small field was treated and one was left untreated, lygus populations later in the season tended toward equalization, partially obliterating the results of the control program. However, a survey made June 8 and 9 showed a mean lygus population of 2.5 per sweep for those fields receiving treatment as compared with a mean population of 7.6 per sweep for the untreated portions of fields.

Perhaps the best measure of the effectiveness of the 1943 control program in this area is a comparison of 1943 lygus populations, seed yields, and viability with similar records of previous years. The data given in table 7 indicate that the viability of the seed produced in 1943 was comparable with that of 1941, which was the only year of low lygus populations since records have been kept for the Albuquerque area. These data also show that lygus populations in 1943 without control were about the same as in 1939 and 1940, when the average percentages of germinating seed produced were 76 and 64 as compared with 81 for 1943.

In 1944 all fields in the Albuquerque area were treated commercially with a pyrethrum-sulphur dust for lygus control except a 7-acre strip in the center of a 20-acre field which was dusted experimentally with a 5-percent DDT dust. This dust was applied at the time of the first pyrethrum-sulphur dust application (June 5), when

Table 7.—Relation of lygus populations to average beet seed yield and viability. Albuquerque, N. Mex., 1939-1943.

Year	Sampling date	Number of lygus bugs per sweep	Average yield per acre, pounds	Average percent of germinating seed*
1939	May 25	3.8	829	76
	June 27	8.4	.....	....
1940	June 1	3.0	1,439	64
1941	June 5	.5	1,195	83
1942	June 8	20.5	233	47
1943	May 25	2.8	.....	....
	June 9	7.6†	1,019	81

*Germination analyses were made by a commercial seed analyst from samples taken from commercially cleaned seed.

†Computed from fields which had not received any treatment for lygus control up to June 9.

the beets were in the pre-blossom stage of development. Population counts taken immediately before treatment indicated the presence of between three and four lygus bugs per sweep in this field. Within 24 hours the lygus population in the portions of the field treated with DDT and with pyrethrum-sulphur had been reduced almost to zero, but by June 15 the population had increased to more than one per sweep in the pyrethrum-sulphur portion, owing largely to additional influxes. In order to prevent the population from increasing more, a second application of pyrethrum-sulphur dust was made. Populaitons in the DDT-treated strip, however, remained at a low level throughout the season. Germination tests on samples of seed taken from this field showed that 71.4 percent of the seed from the portion treated with pyrethrum-sulphur was viable compared with 77.6 percent from the DDT-treated portion. These data indicate that one application of 5-percent DDT gave results equal to if not better than two applications of the pyrethrum-sulphur dust.

In 1945, lygus populations in the Albuquerque area were again high, and all seed beet fields were dusted with a 5-percent DDT dust at the rate of 25 pounds per acre with hand dusters, between June 1 and 7. The plants at this time were in the later pre-bloom to early blossom stage, the most advantageous for applying the dust. Ten portions of fields were left untreated in the area, and on June 19 and 20 lygus population counts were taken in these untreated and comparably treated portions. The mean population for the untreated portions at that time was 11.4 per sweep as compared with 0.6 per sweep for the treated portions, a difference which indicated that excellent control had been obtained. However, seed germination analyses from samples of seed taken from 10 treated and 10 untreated areas showed that, despite the excellent control of lygus obtained

by the DDT applications, very poor seed was produced, and in some cases there were no differences in viability of seed from treated and untreated portions of the field in spite of great differences in lygus populations. The mean percentage of viable seed from the 10 treated areas was 40.2 as compared with 30.1 from the untreated areas. As previously explained, the technique used in cleaning and preparing these samples for germination gives results lower than can be expected from commercial analyses; nevertheless, the seed produced under controlled conditions in the Albuquerque area in 1945 is far lower in viability than would be expected in view of the lygus populations and strongly indicates that other factors also have influenced the viability of seed produced in that area.

Hemet, Calif.—Lygus control on a commercial scale was undertaken in the seed beet fields in the vicinity of Hemet, Calif., in 1944. Some dusting sulphur and some pyrethrum-sulphur were applied by airplane. Results with the pyrethrum-sulphur were disappointing, apparently owing to the substandard quality of the material as shown by chemical analyses.

Detailed lygus population data for the seed beet fields in the Hemet area were not available for 1945, but such information as was available indicated that populations were not high at any time during the season. However, the spring development of the crop in that area was somewhat slower than in the Salt River Valley, Ariz., and we have some evidence that populations of approximately one lygus bug per sweep existed over a comparatively long period of time, probably from May 1 to July 1. The beet seed in the Hemet area was not mature and ready for harvest until the middle or latter part of July. Under those conditions the value of a control program was considered questionable, but, to determine the effect of controlling lygus under those conditions, portions of several fields were treated by airplane with 5-percent DDT dust at the rate of approximately 30 pounds per acre, and portions of the same field were left untreated. Samples of seed for germination analyses were taken from the treated and untreated portions of six fields. These samples indicated that, without exception, the treated portion of the field produced a larger percentage of viable seed than the untreated portion of the same field. The mean percentage of viable seed from the DDT-treated areas was 82.2 as compared with 64.8 for the untreated areas.

Southeastern and Heber Valley, Utah.—Yields and viability of sugar beet seed produced in southeastern Utah in the vicinity of Hurricane, St. George, and Leeds in 1941 and 1942 were low. Insect-population counts taken in the seed beet fields in those areas in early June 1942 showed that large numbers of lygus were present on the

beets at that time; however, the crop was then too far advanced to attempt control. In 1943 surveys of beet fields in these areas were commenced in March and continued until early May, at which time lygus numbers became extremely high (20 to 30 per sweep in some fields). All seed beet fields in southern Utah having 12 or more insects per sweep at the full bloom stage were given one application of a pyrethrum-sulphur dust (similar to the material shown to be effective in small-plot tests at Phoenix, Ariz.). The material was applied with a horse-drawn power duster at the rate of approximately 30 pounds per acre while the plants were in the full bloom to late bloom stage of development. The duster had a 52-inch clearance and was equipped with a canvas trailer. Excellent kills were obtained, ranging from 83 to 97 percent for adults and 94 to 99 percent for nymphs. The seed produced in these southern Utah areas in 1943 averaged 88.9 percent viable, whereas in 1942 when lygus was not controlled the seed averaged 64.2 percent viable. Yields also were somewhat higher for 1943 than for 1942.

Lygus populations in the seed beet fields of southern Utah were low in 1944 and yields were correspondingly high, the viability of the seed was good, and no insecticidal control was necesary. In 1945 high populations again occurred in these areas, and control was undertaken by using the pyrethrum-sulphur dust. Results were poor, however, and seed yields and viability were comparatively low.

In the Heber Valley, in 1945 the effectiveness of a 5-percent DDT dust against lygus was tested by dusting one-half of a seed beet field with this material and leaving the other half of the field untreated as a check. Ground equipment was used, and only one application was made to the plants in the pre-bloom stage at the rate of 30 pounds per acre. There were 4.5 lygus bugs per sweep in the field at the time the dust was applied. Counts taken at 5, 9, 16, and 23 days after treatment showed that populations in the treated portions had dropped to a very low level in 5 days and remained so for at least 23 days, after which time the crop was approaching maturity and was no longer susceptible to injury by this insect. Lygus numbers in the untreated side of the field reached a peak of nearly 10 per sweep 16 days after treatment, and then declined. Germination analyses on samples of seed from the two sides of the field showed 84 percent of viable seed for the treated side as compared with 78 percent for the untreated side.

In one field the 5-percent DDT dust was compared with a 20-percent sabadilla dust and with a pyrethrum-sulphur dust mixture (pyrethrins 0.2 percent). Plots were about 0.14 acre in size, and were arranged in four randomized blocks. The dusts were applied at about 35 pounds per acre with rotary hand dusters when the plants were in full

bloom. Applications were made in the morning when there was no air movement. and they were followed by frequent thunder showers. The lygus population of 6.0 per sweep before treatment decreased to 2.1 per sweep in the untreated plots in 8 days, while in the plots treated with DDT, sabadilla, and pyrethrum the numbers of lygus bugs per sweep 8days after treatment was 0.2, 0.2, and 1.2, respectively. Seed viability at harvest was not appreciably different, as the germination ranged from 93 percent in the DDT plots to 87 percent in the check plots. These data demonstrate the effectiveness of DDT and sabadilla but are not conclusive with respect to the relative efficiencies of these insecticides.

Summary and Conclusions

Preliminary tests were made in laboratory cages to determine the comparative insecticidal value of various materials against *Lygus* spp. and the Say stinkbug (*Chlorochroa sayi* Stal). Materials showing value as insecticides against these insects were further tested against lygus in small experimental plots of seed beets. The best insecticides were then tested on a large scale in commercial seed beet fields with commercial equipment. In general those insecticides giving good results in laboratory cage tests have also been of some value in controlling lygus under field conditions. Sometimes insecticides showing promise in the laboratory cages have not shown comparable results in the field, and a few of the insecticides giving good results in laboratory cages have caused foliage-burn or other damage to the crop.

Small-plot and large-scale experiments have shown dusting sulphur, pyrethrum-extract dusts, and DDT to be of value in controlling lygus in seed beets. Dusting sulphur has been shown to be inferior to the other insecticides in that three to five applications were usually required, only the nymphs were affected to any appreciable degree, and the kill was very slow. Pyrethrum-extract dusts containing 0.2 percent of pyrethrins gave excellent kills especially when used in ground dusters. Its action was fast and the insects died within a few hours. However, the effectiveness of the pyrethrum was soon lost under field conditions, and at least two applications at 10-day or 2-week intervals were usually required, the first application to kill the insects present, and the second to kill the nymphs hatching from eggs deposited in the plants prior to the first application. More than two applications may be necessary if additional influxes of lygus appear. Five-percent DDT, either in pyrophyllite, talc, or dusting sulphur, was found to give better results than the other inseticides. The action of DDT as an insecticide was slower than that of pyrethrum-extract dusts, and it was sometimes 2 or 3 days before the affected

bugs died. However, DDT has retained its insecticidal properties sufficiently under field conditions that one application made in the late pre-blossom to early bloom stage of the beet plants has held lygus populations at a very low level throughout the remainder of the season.

Field tests have shown that 30 pounds per acre of a 5-percent DDT dust were required for maximum results against lygus in seed beets if applications were made by airplane, but if ground equipment was used from 20 to 25 pounds were sufficient. When pyrethrum-extract dust or sulphur was used, best results were obtained with 40 pounds applied by airplane and from 25 to 30 pounds by ground equipment.

Studies are still continuing on the timing of insecticidal dust applications for lygus control, and to date these studies indicate that best results are obtained if the first application is made during the late pre-bloom or early bloom stage of the seed beets. If pyrethrum-extract dust is used, a second application should follow in 10 days or 2 weeks; if DDT is used, the one application will be sufficient.

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Observations on DDT for the Control of Lygus on Beet Seed in Colorado and Montana

ALBERT ISAKSSON[1]

The data here presented are not the results of planned tests but are observations made as opportunity presented itself after application of DDT had been made. They are presented as a matter of record with brief mention of certain facts that may have a bearing upon their evaluation.

Windsor and Johnstown, Colo.—Tables 1 and 2 present the results of counts made in the Windsor and Johnstown districts, Colorado, on the popuplation of Lygus bugs, adults and nymphs, before and after dusting with 5-percent DDT at an approximate rate of 20 to 25 pounds per acre by means of an airplane. The figures presented are averages of 50 sweeps with a standard insect net or with 100 or 150 sweeps in those instances where more than one observer participated.

Table 1.—Average Numbers of Lygus, adults and nymphs, per sweep before dusting and on five dates after dusting with DDT. Dust applied morning of June 21. Windsor and Johnstown, Colo., 1945.

	Before dusting		After dusting									
	6/19		6/21		6/22		6/25		6/28		7/6	
Field	A[1]	N[2]	A	N	A	N	A	N	A	N	A	N
Windsor 1	.40	1.02	.30	.98	.07	.10	.03	.00	.10	.00	.22	.00
Windsor 2	.31	1.99	.20	1.30	.06	.05	.07	.02	.20	.01	.10	.00
Windsor 3	.38	2.18	.20	.84	.06	.05	.05	.00	.14	.00	.17	.03
Windsor 4	.17	.46	.15	.70	.40	.01	.08	.00	.23	.00	.20	.11
Windsor 5	.21	1.60	.07	.07	.03	.02	.07	.07	.11	.00	.11	.00
Mean	.29	1.45	.18	.78	.05	.05	.06	.02	.14	.00	.16	.03
	6/20		6/21		6/22		6/25		6/28		7/6	
Johnstown 1	.40	1.60	.46	.78	.22	.12	.31	.17	.53	.17	.80	.17

[1]Adults
[2]Nymphs

The dusting was done June 21 between sunrise and 8:30 a. m. The majority of the plants were approximately in the early blossom-

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Table 2.—Average numbers of Lygus, adults and nymphs, per sweep before dusting and on five dates after dusting with DDT. Dust applied morning of June 21. Undusted strip compared with dusted major part of field. Windsor, Colo., 1945.

	Before dusting		After dusting									
	6/19		6/21		6/22		6/25		6/28		7/6	
Field	A[1]	N[2]	A	N	A	N	A	N	A	N	A	N
Windsor 3												
Undusted	.38	2.18	.56	1.62	.21	.28	.17	.15	.20	.00	.70	.22
Dusted	.38	2.18	.20	.84	.06	.05	.05	.00	.14	.00	.17	.03

[1]Adults
[2]Nymphs

ing stage, and the Lygus population at the time was considered relatively low. There was very little wind at the time of application, and at Windsor the direction, when noted, was toward the east or away from the undusted strip of field 3.

The first check on the effect was made in the afternoon of the day of dusting. The day was warm without appreciable wind and some effect of the dusting was noted. Counts were made also on the following day, June 22, when a great reduction in the Lygus population was noted. At this time a reduction in population was noted also in the undusted strip of field 3. The reason for this reduction may have been a drift westward of some of the dust once deposited in the main part of the field. All counts after dusting were made on afternoons.

On June 28 nymphs as well as adults were found on an undusted steckling field in the northeast corner of the west farm, while on a similar field in a corresponding location on the east farm, numerous adults were noted but no nymphs. On July 6 these steckling fields showed both adults and nymphs in about equal numbers. At the same time three alfalfa fields on the east farm sampled in one location each yielded few to relatively many adults (up to .40 per sweep), but nymphs were either very scarce or absent in a mass of aphids which practically clogged the bottom part of the net.

Experiment Station, Longmont, Colo.—Table 3 presents data obtained at the Longmont Experiment Station from treated patches of pedigreed seed. Five-percent DDT was used at a rate insuring good coverage. These patches were relatively small and any immigration of Lygus from surrounding fields would have been instantly reflected in following counts. Twenty-five sweeps with an insect net were the basis for each individual count.

Table 3.—Average combined numbers of adults and nymphs per sweep before dusting and on four dates after dusting with DDT. Longmont Experiment Station, 1945.

	Before dusting		After dusting							
	6/20		6/22		6/28		7/1		7/5	
Patch	A[1]	N[2]	A	N	A	N	A	N	A	N
5 E	.8	.2	.2	.1	.3	.0	.2	.1	.2	.1
5 W	.1	.0	.0	.0	.5	.1	.8	.2	6.0	3.0
6	.4	.2	.1	.4	.0	.0	.1	.0	.1	.1
11	.8	.1	.2	.0	.2	.0	.3	.1	.4	.3
14	1.4	.4	.2	.0	.6	.1	.5	.2	.8	.5
17	1.3	.6	.2	.0	.2	.1	.3	.2	.8	.3
18	.8	.2	.2	.0	.2	.0	.2	.1	.3	.2
19	1.5	1.2	.1	.1	.2	.0	.3	.1	.2	.1
21	.6	.3	.1	.1	.2	.0	.2	.1	.3	.0
Mean	.86	.36	.14	.08	.27	.03	.32	.12	1.01	.51

[1]Adults
[2]Nymphs

Billings, Mont.—Table 4 presents results with DDT for lygus control from Billings, Mont. In this case 10-percent DDT was applied at a rate insuring good coverage to one half of a breeding group which was compared with the undusted area. Fifty sweeps with an insect net were the basis for each individual count.

Table 4.—Average numbers of Lygus per sweep before dusting and on three dates after dusting with DDT. Billings, Mont., 1945.

	Before dusting	After dusting		
	6/21[1]	6/22[2]	6/23[1]	6/25[2]
Undusted	.52	.76	1.22	1.22
Dusted	.52	.00	.06	.02

[1]Only adult bugs found
[2]Numerous nymphs present with the adults

Summary and Conclusions

Dusting of seed beets with 5-percent DDT was followed by a reduction of the Lygus population by 80 to 98 percent in several fields, as indicated by counts made 1 to 4 days after application. At the same time a much less pronounced reduction in the number of Lygus was noted in some other dusted fields and seed beet patches of small size. It seems certain that the reductions mentioned were largely or exclusively due to the DDT treatments, and it is probable that migration of Lygus from surrounding areas may largely have obscured the effect of the DDT in some instances, especially in the small patches. Counts made 7 and 15 days after the dusting indicated an increase in adult Lygus, although the average number still was only approximately one-half of the pre-dusting number in five of the fields.

On the basis of the observations made, the DDT appears very promising as a means of Lygus control.

A Preliminary Report on the Control of Sugar-Beet Nematode with Two Chemicals, D-D and Dowfume W15

GERALD THORNE[1] and VERNAL JENSEN[2]

Soil fumigation for the control of nematodes and other soil inhabiting pests was impractical on a field scale until the recent discoveries of D-D and Dowfume W15. Previously the chemicals known as efficacious nematocides were too expensive for use except in greenhouses and on limited areas producing high-priced specialty crops.

D-D, a mixture of 1,2-dichloropropane[3] and 1,3-dichloropropene[3] (Syn: 1,3-dichloropropylene), is produced by the Shell Chemical Corporation and was first reported as a successful nematocide by Carter in 1943 (*1*)[4]. The possibilities of D-D as a soil fumigant appeared to be so outstanding that in 1943 and 1944 tests were conducted by many federal, state, and private agencies, and a large proportion of these gave successful control of nematodes and certain other soil-inhabiting pests. In 1945, extensive experimental work was carried on at many points and in addition large commercial applications were made, principally in California and Hawaii, with small acreages in Utah, Idaho, Texas, and Oregon and on Long Island, N. Y.

Dowfume W15 consist of a 15-percent solution of 1,2-dibromoethane[3] (Syn: ethylene dibromide) in a low grade gasoline and is marketed by The Dow Chemical Company. It was first tested on a few small plots near Seal Beach, Calif., in 1944, and its nematocidal properties proved to be so promising that in the spring of 1945 several large demonstration plots were treated, most of them generally successful.

The sugar beet nematode presents one of the most difficult problems in soil fumigation because of the brown cyst stage in which the eggs are very effectively protected. Data on the killing range of chemicals indicate that for this species it is less than half that for most other plant parasitic species and therefore heavier applications will probably be required to obtain successful control. Results to date show that one good crop of beets can be produced even on the most heavily infested soils if properly treated, but it still remains

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[3]Name approved by the International Union of Chemistry.

[4]Italic numbers in parentheses refer to literature cited.

very doubtful if a second crop can be grown without additional treatment.

The work here reported was conducted by the senior writer near Midvale, Utah, in 1944 and 1945, and by both writers at Lewiston, Utah, in 1945.

Field No. 1, 1944.

This field was laid out in 32 plots, each 20 feet long and 4 rows wide. D-D was applied on alternating plots at four rates per acre: 2,000 pounds (10 cc injections, 9 inches by 9 inches apart, in staggered rows); 1,000 pounds (5 cc, 9 inches by 9 inches); 500 pounds (10 cc, 18 inches by 18 inches); and 250 pounds (5 cc, 18 inches by 18 inches). Applications were made by measuring exact amounts from a graduate and pouring them into holes 6 inches deep made with a ½-inch probe. Applications were made May 6 when the soil moisture was 14 percent and temperature 58° F.

The two heavier applications caused a delay in germination of 1 week with subsequent severe injury of seedlings. Slight retardation was also noted on the 500-pound plots.

Distinct stimulation of growth was noted early in July on the 250-pound plots and to a lesser degree on the 500-pound. Fortunately the autumn was late and digging was delayed until November 9. This partly made up for the late date of planting and gave excellent yields as is shown in the following table.

Amount of D-D per acre	Yield of sugar beets per acre		Gain or loss
	Treated plots	Untreated plots	
2,000 pounds	8.29 tons	10.73 tons	− 2.44
1,000 pounds	14.14 tons	12.51 tons	+ 1.53
500 pounds	20.15 tons	12.35 tons	+ 7.70
250 pounds	27.30 tons	11.70 tons	+15.60

The abnormally high yield of 27.30 tons on the 250-pound plots was most unexpected and was probably due to two factors which produce the so-called "stimulation" by D-D:

1. Control of other species of nematodes, e. g. *Pratylenchus* sp., and perhaps other soil organisms which are not generally recognized as being inimical to plant growth.

2. Destruction of nitrifying bacteria, thus releasing ammonia, produced by decaying organic matter, for immediate use of the plants, as demonstrated in Hawaii by Tam (2).

The moderately good yields of the untreated plots were due to

the fact that in 1943 beets were grown on the field and in this particular area the nematodes practically killed out the crop, thereby giving something of a "trap crop" effect and allowing fertility to accumulate.

Had application been made in the fall, comparable yields would doubtless have been produced on the 2,000-pound and 1,000-pound plots, for then the D-D would have evaporated from the soil before planting. As it was, a strong odor remained in the plots through August and the sugar beets had branching roots which spread out near the surface to escape the pool of gas lying below.

Field No. 2, 1945

This field was known to be heavily infested with sugar beet nematodes but had produced an 18-ton crop of beets in 1944 following a 5-year rotation of alfalfa and grain. Strip plantings were made in 1945 and will be repeated in 1946 to determine the possibilities of growing a second crop after one treatment. Applications were made April 28 with soil moisture of 13 percent and temperature 44° F. at 6-inch depth. Yields are shown as follows:

Amount of chemical per acre	Yield of sugar beets per acre		
D-D	Treated plots	Untreated plots	Gain
500 pounds	14.10 tons	2.86 tons	+11.24 tons
500 pounds	15.92 tons	4.92 tons	+11.00 tons
250 pounds	17.74 tons	3.71 tons	+14.03 tons
250 pounds	18.00 tons	4.55 tons	+13.45 tons
Dowfume W15			
400 pounds	13.0 tons	3.83 tons	+ 9.75 tons
200 pounds	15.99 tons	6.24 tons	+ 9.75 tons

Retardation of germination and injury to seedlings occurred on the 500-pound plots and are reflected in the yields. Many of these beets lacked the typical long taproot and possessed numerous lateral roots as if a pool of gas had remained at a level of 5 or 6 inches. Considering the time of growth, May 8 to October 10, the yields generally are about as good as might be expected.

Low yields of untreated plots are typical of the result of attempting two crops of beets in succession on nematode-infested fields, even after long crop rotations.

The Dowfume W15 plots were the most conspicuous of all from the standpoint of top growth and root formation, but obviously there was a lack of balance in the fertilizing elements present, resulting

in lower yields from the 400-pound plot. Sugar on this plot was only 13.8 percent compared with 15 to 17 percent on the others.

Field No. 3, 1945

The Lewiston, Utah, district has a large acreage infested with sugar beet nematodes on which it is difficult to grow a normal crop even after rotations of 5 years or more. The field selected had been in alfalfa 5 years, followed by wheat. Application was made during plowing by means of an applicator driven from the power take-off of a farmall tractor which placed the chemical in a 6-inch band just in front of the plow where it was immediately covered by the furrow.

During hot days, tops of the beets on the treated strips remained upright while those on the check strips wilted badly. Yields of treated plots were somewhat below expectations because of a low level of soil fertility; they are shown in the following tabulation:

Amount of chemical per acre	Yield of sugar beets per acre		Gain or loss
	Treated plots	Untreated plots	
D-D 500 pounds	18.12 tons	13.04	+5.08
D-D 500 pounds	14.09 tons	10.62	+3.47
D-D 250 pounds	16.07 tons	13.75	+2.32
D-D 250 pounds	14.37 tons	8.45	+5.92
W15 200 pounds	11.03 tons	12.50	—1.47

The Dowfume W15 plot had excellent top growth but, as in Field No. 2, the roots lacked weight. Work planned at Lewiston for 1946 includes an extensive series of fertilizer tests on fields treated with D-D and Dowfume W15, and it may be advisable for all investigators to consider this phase in planning work with either of the chemicals mentioned in order to benefit most from the "stimulation" which is so frequently noted.

Some nematodes invariably remained alive even in the treatments of heaviest application, especially in the top 4 inches of soil and below the 20 to 24 inch levels, and by the end of the season large populations were visible on the roots of sugar beets from all plots.

A delay of 7 to 10 days is necessary between D-D application and planting. If the application is made in the spring, this may give time for the soil to dry out until the seed will fail to germinate. Therefore in the mountain states it may frequently be best to make application in the fall. The field to be treated should be planted with grain, peas, early potatoes, or some other crop which can be removed in the late summer or early fall. It can then be irrigated, plowed, and worked down and the D-D applied while soil temperature is still 50° F. or above. The grower can then take advantage of spring moisture and plant just as early as the season permits. Dowfume W15 does

not have so great a disadvantage since planting can follow treatment within 3 or 4 days. Fields just broken from alfalfa or pasture, or those with large quantities of cornstalks or other trash in them, should not be treated since tests have shown that masses of sod are not penetrated by the gas and that roots, trash, and clods allow much of the gas to escape from the soil.

The optimum conditions for chemical application, based on available information, are just about the same as those for planting. If soil moisture and temperature are suitable for planting, then the field is in good condition for treatment and applications made under these conditions should give satisfactory results.

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Preliminary Tests on Control of Insects In Stored Segmented Seed

C. E. CORMANY[1]

Insects commonly attacking stored grains have been found in segmented sugar beet seed after prolonged periods of storage. Seldom have these insects been found in whole seed. No doubt the exposed seed germs of segmented beet seed, plus the dust or "flour" from the shearing process which accumulates on the seed units, afford greater feeding possibilities for the insects.

During recent years Dr. R. T. Cotton and Dr. J. C. Frankenfeld of the U.S.D.A. Agricultural Research Administration, Bureau of Entomology and Plant Quarentine (*1*) (*2*)[2] have conducted much research on the treatment of stored grain to protect it from storage insects. Both poisonous and non-poisonous types of dusts have been used in their work. Of the non-poisonous dusts, finely powdered magnesium oxide has been found to kill the insects and act as a repellant against re-infestation. DDT dust has been the most promising of the poisonous kinds of chemicals used.

A preliminary study was conducted by the author during the summer of 1945 to determine the repelling or killing effect on Indian meal moth *(Plodia interpunctella)* of certain materials already available. The materials included DDT, Sabadilla, Pyrocide, Pyrax, Arasan, "moth balls", and Dichloricide.

The conditions of the test were certainly much more severe than any normally encountered in the storage of segmented sugar beet seed.

The tests were conducted at Grand Junction, Colo., and Sheridan, Wyo. The segmented seed was all the same variety, 2 pounds in a paper bag constituting a lot or treatment, and all treatments were duplicated. An attempt was made (part A) to determine if the larvae of the Indian meal moth would move into lots of treated seed and (part B) to determine if larvae of this insect could survive on treated seed.

In studying the movement from infested to insect-free seed (part A), 2-pound paper bags of clean segmented seed treated as shown in table 1 were placed in open boxes, and between the bags and completely surrounding them was placed waste material from the shearing operation which was heavily infested with Indian meal moth larvae.

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[1]Chief Agronomist, Holly Sugar Corporation, Sheridan, Wyo.

[2]Italic numbers in parentheses refer to literature cited.

Table 1.—Indian meal moth larvae in seed treatment tests.

Treatment of seed	Live larvae present per pound of segmented sugar beet seed			
	Part A		Part B	
	At start	After 4 months	At start*	After 4 months
Check—untreated	0	152	25	120
Inside of bag walls treated with DDT	0	56	25	5
Moth balls (one per pound)	0	633	25	4
Dichloricide (1gram per pound)	0	258	25	1
DDT 3 percent (one oz. per 100 pounds)	0	49	25	1
DDT 3 percent 1½ ozs. per 100 pounds)	0	35	25	1
Sabadilla (10 ozs. per 100 pounds)	0	239	25	5
Pyrocide "10" (1 oz. per 100 pounds)	0	165	25	6
Pyrax (12 ozs. per 100 pounds)	0	160	25	2
Arasan (16 ozs. per 100 pounds)	0	20	25	2

*Actually introduced by hand.

The mouths of the bags were left open. Over the boxes containing the test material was thrown a light canvas cover. The seed treated with moth balls and dichloricide was placed in boxes separate from the other eight treatments.

After 4 months exposure of the small lots of seed to the insect-infested waste material the bags of seed were examined for the presence of insects. Live larvae were found in all bags regardless of treatment but those treated with Arasan and DDT dusts contained fewer than the other treatments, indicating that these materials were more effective as repellants (see table 1, part A). The presence of DDT on the inside lining of the bag may have considerable promise, since the insects entering the bagged seed generally follow the inside bag wall for a short distance before going into the seed, except in direct punctures of bags.

In Part B of the test, to each 2-pound bag of clean segmented seed were added 50 live Indian meal moth larvae and the bag sealed up, the purpose being to determine whether the materials on the seed would kill the insects. Four months later, counts were made for live insects and in all cases except the untreated check the mortality was great. In lots treated with DDT and dichloricide only one live insect was found, giving a kill of 96 percent. In the lots treated with Pyrax (non-poisonous) and Arasan two live larvae remained, while in seed stored in bags with inside walls treated with DDT five live ones were present. The count on the check or untreated lots showed 120 live insects or about a 5 to 1 increase over the original (see table 1, part B).

Under the conditions of these tests it appears that dusting segmented sugar beet seed with DDT dusts before storing was much more effective in keeping away live insects than any other treatment except Arasan. DDT on the walls of the bags was also effective. When insects were placed in lots of seed already treated, the DDT dusts and Dichloricide were most deadly.

Further tests under more nearly normal conditions are planned. Powdered magnesium oxide will be thoroughly tested since it is a non-poisonous material and has shown such great promise in stored grains.

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Lygus Control on Sugar Beet Seed Isolation Plots By Dusting With DDT

C. E. CORMANY

In the initial increases of breeding stocks of sugar beet seed it is quite essential that a large yield of good quality seed be produced. Generally these increases are small in area, usually less than ¼ acre, and are plantings of mother beets or steckling roots.

Satisfactory seed yields can be assured by maintaining a high soil fertility level and optimum care throughout the growing season. Quality as reflected by germination is much harder to maintain, and many times the yields are high but quality low.

These lower germinations are caused principally by the attacks of lygus (*Lygus elisus* and *Lygus oblineatus*). Dusting to control lygus by killing the insects or repelling them has proved very satisfactory. Many chemicals have been tried in dust form on these isolations but none has been so effective as DDT in killing the lygus.

Two or three dustings per season using about 25 to 30 pounds of 3-percent DDT has proved very effective in the control of this insect on the isolation plots at the Holly Experiment Station, Sheridan, Wyo.

Results of the control by one dusting are reported in the following table. The day was not ideal for dusting, it being slightly windy with frequent gusty periods which drifted the dust off several plots.

The kill was greater by 10 percent at the end of the second day than it was 24 hours after dusting, and probably had counts been made at 72 hours it would have been still higher. The greatest kills have been recorded on the third and fourth days in some instances.

Table 1.—Results of dusting seed beets with DDT (3-percent) at 27 pounds per acre, July 10, 1945.

Plot No.	Lygus count*			Percentage kill	
	Before dusting	24 hours after dusting	48 hours after dusting	24 hours after dusting	48 hours after dusting
187	11	2	0	81.8	100
188	4	1	0	75.0	100
189	6	1	0	83.3	100
195	4	0	2	100.0	50
199	8	2	1	75.0	87.5
200	6	1	1	83.3	83.3
202	28	5	3	82.1	89.3
203	8	3	1	62.5	87.5
205	14	8	1	42.8	92.8
225	6	1	1	83.3	83.3
			Averages	76.9	87.4

*Total lygus (green and brown) per 50 sweeps of the net.

Lygus populations on these plots were not as high as in previous years, the average being 9½ lygus per 50 sweeps.

The advtange of dusting for controlling lygus is also reflected in germination records. The average germination of 19 isolations dusted with DDT was 83 percent and for 20 isolations not dusted 62 percent, or a gain of 21 percent due, to a large extent, to the dusting.

Effect of Different Soil and Seed Treatments on the Control of Seedling Diseases of Sugar Beets Under Controlled Conditions[1]

M. M. Afanasiev and H. E. Morris[2]

This investigation to study the effect of different soil and seed treatments in relation to the control of seedling diseases of sugar beet consists of three parts:

1. Different seed treating compounds.

2. Different amounts of treble superphosphate applied to the surface of sugar beet seeds.

3. Different amounts of sodium nitrate and treble superphosphate applied to the surface of sugar beet seeds.

I. Effect of Different Seed Treating Compounds on the Control of Seedling Diseases of Sugar Beets

Previous experiments conducted with treatments of sugar beet seeds with Ceresan, New Improved Ceresan, and copper sulphate showed that these chemicals had very little value in controlling root rots of sugar beets under Montana conditions. (*1*, *2*, *3*, *4*, *5*, *6*)[3]. In recent years several new chemicals have appeared on the market which are being recommended for seed treatments.

Experiments were conducted with six different fungicides which included some new chemicals to determine their value for the control of root rots (table 1).

These chemicals were tested on both whole and segmented sugar beet seeds, since in the last few years the use of segmented seeds has been a rather general practice.

Soil from the third year of the alfalfa plot in Rotation 62 B at the Huntley Field Station, Huntley, Mont., was used in greenhouse flats holding about 24 pounds of soil. A high percentage of seedling diseases always occurred in this soil in previous studies. One row of whole and two rows of segmented seed, each containing 20 seeds, were planted in each flat.

The seeds were treated with the chemicals and planted immediately. Regular readings of healthy and diseased beet plants were

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[1]Contribution from Montana State College Agricultural Experiment Station, Paper No. 84, Journal Series.

[2]Montana Agricultural Experiment Station, Bozeman, Mont.

[3]Italic numbers in parentheses refer to literature cited.

Table 1.—Amounts of different seed and soil treatments used.

Seed treatments used			Soil treatments used	
	Amt. per 100 lbs. of beet seed		Per one flat of soil	
Name of chemical	Whole Ounces	Segmented Ounces	Calcium nitrate Grs.	Treble superphos. Grs.
1. Ceresan	16	24	....	....
2 New Improved Ceresan	6	8	....	....
3. Spergon	15	22.5	....	....
4. Arasan	4	6	....	....
5. Thiosan	15	22.5	....	....
6. Red copper oxide	24	36	....	....
7. Check	....	....	16.2	1.8
8. Check	....	....	16.2	1.8
			Manure (1/5 of soil volume)	
9. Check	....	....	....	....

taken approximately for 1 month after emergence. The plants in all flats were then harvested and final readings pertaining to the amount of disease and size and weight of seedlings were taken.

Results.—Table 2 presents the results of this study. Plants developing from seeds treated with all chemicals had a very high amount of seedling disease. In fact, with the exception of a few plants grown from the segmented seeds treated with Spergon and Thiosan, all seedlings were diseased. The height of the seedlings in all flats planted with treated seeds varied between 5 and 7 cm. and the weight between 0.13 and 0.81 gram per plant. There was no significant difference either in height or in weight between the seedlings grown from either whole or segmented seeds.

Beet plants developing from whole and segmented beet seeds in soil fertilized with nitrogen and phosphorus had 53.1 and 33.3 percent diseased seedlings respectively. These plants were considerably taller (14 cm.) and heavier (1.66 and 1.82 grams per plant respectively for whole and segmented seeds) than those grown from the treated seeds in unfertilized soil.

Beet plants developing from untreated sugar beet seeds in soil fertilized with nitrogen, phosphorus, and manure had 45.9 and 34.6 percent of diseased seedlings grown from whole and segmented seeds respectively. These plants were considerably taller (14 cm.) and heavier (1.75 and 2.00 grams per plant respectively) than those grown from the treated seeds in unfertilized soil.

Plants grown from untreated seeds planted in unfertilized soil were almost all diseased (100.0 and 96.2 percent respectively for whole and segmented seeds). The height and weight of these plants were

Table 2.—Effect of different seed treatments on the control of seedling diseases of sugar beets.

Flats No.	Seed		Soil fertilized	Sugar beet seedlings				At Harvest	
				Number		Percent			
	Treated with	Type used		Healthy	Diseased	Healthy	Diseased	Height of beet tops Cm.	Weight per plant Gr.
1-a	Ceresan	Whole	None	0	96	0.0	100.0	5	0.17
b	Ceresan	Segm.	None	0	35	0.0	100.0	5	0.13
2-a	N. I. Ceresan	Whole	None	0	97	0.0	100.0	6	0.22
b	N. I. Ceresan	Segm.	None	0	36	0.0	100.0	6	0.42
3-a	Spergan	Whole	None	0	86	0.0	100.0	7	0.52
b	Spergon	Segm.	None	5	23	17.9	82.1	7	0.81
4-a	Arasan	Whole	None	0	90	0.0	100.0	7	0.41
b	Arasan	Segm.	None	0	36	0.0	100.0	7	0.34
5-a	Thiosan	Whole	None	0	105	0.0	100.0	6	0.21
b	Thiosan	Segm.	None	2	35	5.4	94.6	6	0.20
6-a	Red copp. ox.	Whole	None	0	87	0.0	100.0	6	0.26
b	Red copp. ox.	Segm.	None	0	39	0.0	100.0	6	0.19
7-a	Check	Whole	NP	45	51	46.9	53.1	14	1.66
b	Check	Segm.	NP	16	8	66.7	33.3	14	1.82
8-a	Check	Whole	NPM	40	34	54.1	45.9	14	1.75
b	Check	Segm.	NPM	17	9	65.4	34.6	14	2.00
9-a	Check	Whole	None	0	78	0.0	100.0	7	0.28
b	Check	Segm.	None	1	25	3.8	96.2	7	0.32

about the same as the average for those grown from the treated seeds planted in unfertilized soil.

Conclusion.—These results show that different seed treating compounds used in this experiment produced very little control of root rots of young sugar beets. It is evident that any fertilization which produces vigorous, fast-growing seedlings is more important in controlling root rots than different seed treatments. The results reported here confirm those obtained in our previous investigations. (*1, 2, 3, 4, 5, 6*)

II. Effect of Different Amounts of Treble Superphosphate Applied to the Surface of Sugar Beet Seeds on the Control of Seedling Diseases

It is a well-known fact that when sugar beets are planted in well-fertilized soil the seedlings are usually vigorous and show a considerable degree of resistance to different root-rot-producing soil organisms.

In this study an experiment was conducted to evaluate the effect of treble superphosphate on control of seedling diseases when it is applied to the surface of sugar beet seed instead of to the soil. It was thought that fertilizers placed on the surface of sugar beet seeds might produce considerable beneficial effects on the developing young plants, since it would be so close to the growing plant.

Segmented sugar beet seeds treated with different amounts of treble superphosphate of 300 mesh (fume) were supplied by the Great Western Sugar Company, Longmont, Colo. There were seven lots of sugar beet seeds. Each of six lots had been treated with the following amount of treble superphosphate to 100 pounds of sugar beet seeds: 100 pounds, 70 pounds, 40 pounds, 20 pounds, 10 pounds, and 5 pounds. The treble superphosphate was stuck to the surface of the sugar beet seeds with glue. The seventh lot of seeds was untreated.

The same type of greenhouse flats and soil from the same source were used in this experiment. Six flats were planted, each with one of the above-mentioned lots of seeds, and the seventh with the untreated check seeds. Each flat was planted with three rows of 20 segmented seeds to a row. Another duplicate set of seven flats was planted with seeds as indicated above and to each flat of this set 15.7 grams of sodium nitrate, 1.8 grams of treble superphosphate, and 1/5 of manure (on the basis of soil volume) was added. Regular readings of healthy and diseased plants were taken approximately for 1 month after emergence. At the end of this period the plants in all flats were harvested and final readings pertaining to the amount of disease and size and weight of seedlings were taken.

Table 3.—Effect of different amounts of treble superphosphate (fume) applied to the surface of sugar beet seeds for the control of seedling diseases.

No. Flats	TSP* (fume) added to 100 pounds seeds Pounds	Fertilizers added to soil	Sugar beet seedlings				At harvest	
			Number		Percent		Height of beet tops Cm.	Weight per plant Gr.
			Healthy	Diseased	Healthy	Diseased		
1-a	100	None	13	43	23.2	76.8	7	0.68
b	100	NPM	40	7	85.1	14.9	15	4.46
2-a	70	None	15	46	24.6	75.4	7	0.71
b	70	NPM	42	1	97.7	2.3	17	6.55
3-a	40	None	10	53	15.9	84.1	6.5	0.58
b	40	NPM	42	4	91.3	8.7	18	5.22
4-a	20	None	8	55	12.7	87.3	7	0.73
b	20	NPM	52	6	89.7	10.3	16	5.00
5-a	10	None	0	61	0.0	100.0	5	0.27
b	10	NPM	38	4	90.5	9.5	15	5.88
6-a	5	None	0	65	0.0	100.0	5	0.29
b	5	NPM	50	4	92.6	7.4	16	5.21
7-a	None	None	0	70	0.0	100.0	5	0.22
b	None	NPM	57	6	90.5	9.5	17	4.30

*Treble superphosphate

Results.—The results of this experiment are reported in table 3. The plants grown from all treated seeds in unfertilized soil had between 75.4 and 100 percent of seedlings diseased. The plants grown from seeds treated with larger amounts of treble superphosphate (100, 70, 40, and 20 pounds per 100 pounds of seeds) had slightly less seedling diseases than those grown from seeds treated with small amounts of treble superphosphate (10 and 5 pounds per 100 pounds of seeds). The height of the tops of individual plants grown from treated seeds planted in unfertilized soil varied between 5 and 7 cm. and the weight between 0.27 and 0.73 gram. Again, the plants grown from lots of seeds treated with larger amounts of treble superphosphate were taller and weighed more (0.58 to 0.73 gram per plant) than those grown from seed lots treated with small amounts of treble superphosphate (0.27 to 0.29 grams per plant).

The plants grown from untreated seeds planted in unfertilized soil had 100 percent disease and individual plants averaged 5 cm. in height and 0.22 gram in weight.

Plants grown from all treated seeds planted in fertilized soil had between 2.3 and 14.9 percent of seedling disease, and varied between 15 and 18 cm. in height and between 4.46 and 6.55 grams in weight. The plants grown from untreated seeds planted in fertilized soil had 9.5 percent of seedling disease and the plants averaged 17 cm. in height and 4.30 grams in weight. The experiment was repeated with similar results.

Conclusions.—The results show that when treble superphosphate is used in large amounts (100, 70, 40, and 20 pounds per 100 pounds of seeds) it apparently produces a beneficial effect on the developing young beets in unfertilized soil. This was indicated by the slight reduction in seedling diseases and by an increase in the weight of individual beets. Small amounts of treble superphosphate (10 and 5 pounds per 100 pounds of seeds) failed to produce any beneficial effect on sugar beet plants in the same type of soil.

The importance of well-fertilized soil for growing of sugar beets is again shown in this test. Beets grown in fertilized soil either from seeds treated with treble superphosphate or from untreated seed showed a low amount of seedling disease and a much greater weight per plant than those grown from the same type of seed in unfertilized soil.

In general this test shows that if a soil is well supplied with organic matter and mineral nutrients in proper relationship with one another, no benefit is to be gained from treating sugar beet seeds with treble superphosphate. Plants grown from untreated seeds in fertilized soil (7b) produced just as good results as those grown from treated ones in the same soil (1b to 6b).

III. Effect of Different Amounts of Treble Superphosphate and Sodium Nitrate Applied to the Surface of Sugar Beet Seeds on the Control of Seedling Diseases

When treble superphosphate was applied to the surface of sugar beet seeds only a slight beneficial effect of this nutrient was observed on the reduction of seedling diseases and on the increase in growth of sugar beets (Part II).

It was thought that if both nitrogen and phosphorus were applied to the surface of sugar beet seeds, possibly a greater beneficial effect in reducing seedling diseases and also more prolific growth of young sugar beets could be obtained. Therefore, to find an answer to this question the following study was conducted.

Whole and segmented sugar beet seeds were used. In order to make the fertilizers adhere to the surface of the sugar beet seeds, liquid glue (LePage's, Gloucester, Mass.) was used. One part of this glue was mixed with four parts of water. In spraying the sugar beet seeds with a solution of this glue, approximately 8 to 10 cc. were used per each 25 grams of sugar beet seeds.

Sodium nitrate and treble superphosphate were used as the fertilizers. The sodium nitrate was ground and sifted through a 100 mesh screen. In a preliminary test with only one application of

glue, 25 grams of either whole or segmented seeds retained only 14 grams of treble superphosphate and much more sodium nitrate which readily dissolves in a solution of glue. Therefore 14 grams of treble superphosphate and the same amount of sodium nitrate, alone or in a combination, were used as a maximum amount for 25 grams of seeds in this experiment. It is quite possible that these chemicals in the maximum of their adherence may have a toxic effect on the seeds, so for this reason they were used in the three gradually decreasing amounts.

Table 4.—Amounts of treble superphosphate and sodium nitrate used for treating sugar beet seeds.

Whole or segmented seeds			
Amount of chemicals used on the basis of 25 grams of seeds		100 pounds of seeds	
Sodium nitrate	Treb. superphos.	Sodium nitrate	Treb. superphos.
Grams	Grams	Pounds	Pounds
14	14	56	56
7	7	28	28
3.5	3.5	14	14

Soil treatments with nitrogen, phosphorus, and manure were also used as checks. The same type of greenhouse flats and the same type of soil were used in this experiment as were reported for the first and second parts of this study.

Ten flats of soil were planted with whole and segmented sugar beet seeds. Flats 1, 2, and 3 were planted with whole seeds which were treated with gradually decreasing amounts of chemicals. The seeds planted in the first row were treated with sodium nitrate and treble superphosphate. Those planted in the second row were treated only with sodium nitrate, and those planted in the third row only with treble superphosphate. The same plan was used for planting flats 4, 5, and 6 except that these flats were planted with segmented seeds (table 5).

Flats 7 and 8 (table 5) were planted with untreated seeds without glue. The first row in each flat was planted with whole seeds and the remaining two rows with segmented seeds. The soil of flat 7 was fertilized with 15.7 grams of sodium nitrate and 1.8 grams of treble superphosphate. The soil of flat 8 was fertilized with the same amounts of chemicals as soil of flat 7 and in addition manure was added on the basis of 1/5 of the soil volume. Flats 9 and 10 were checks. Flat 9 was planted with untreated seeds without glue and flat 10 with the same kinds of seeds coated with glue. The first

Table 5.—Effect of different amounts of treble superphosphate (fume) and sodium nitrate applied to the surface of sugar beet seeds for the control of seedling diseases.

Flats No.	Rows No.	Fertilizers used on basis of 100 pounds of seeds		Soil fertilized	Type of seeds used	Sugar beet seedlings				At harvest	
						Number		Percent		Height of beet tops	Weight per plant
		$NaNO_3$ pounds	Tr. superph. pounds			Healthy	Diseased	Healthy	Diseased	Cm.	Gr.
1	1	56	56	None	Whole	0	32	0.0	100.0	6	0.79
	2	56		None	Whole	1	43	2.3	97.7	5	0.45
	3		56	None	Whole	0	42	0.0	100.0	5	0.39
2	1	28	28	None	Whole	0	38	0.0	100.0	4	0.31
	2	28		None	Whole	0	25	0.0	100.0	5	0.45
	3		28	None	Whole	0	33	0.0	100.0	6	0.52
3	1	14	14	None	Whole	0	36	0.0	100.0	5	0.29
	2	14		None	Whole	0	36	0.0	100.0	4	0.28
	3		14	None	Whole	0	24	0.0	100.0	4	0.38
4	1	56	56	None	Segm.	1	16	5.9	94.1	7	1.25
	2	56		None	Segm.	1	15	6.2	93.8	4	0.31
	3		56	None	Segm.	1	20	4.8	95.2	6	1.05
5	1	28	28	None	Segm.	0	17	0.0	100.0	5	0.38
	2	28		None	Segm.	0	13	0.0	100.0	4	0.25
	3		28	None	Segm.	0	22	0.0	100.0	5	0.56
6	1	14	14	None	Segm.	0	23	0.0	100.0	5	0.36
	2	14		None	Segm.	0	24	0.0	100.0	5	0.33
	3		14	None	Segm.	0	20	0.0	100.0	5	0.30
7	1	None	None	NP	Whole	18	13	58.1	41.9	15	3.03
	2	None	None	NP	Segm.	24	4	85.7	14.3	15	4.04
	3	None	None	NP	Segm.	11	9	55.0	45.0	14	4.16
8	1	None	None	NPM	Whole	21	13	61.8	38.2	18	4.61
	2	None	None	NPM	Segm.	21	2	91.3	8.7	16	6.41
	3	None	None	NPM	Segm.	21	2	91.3	8.7	16	4.52
9	1	None	None	None	Whole	0	28	0.0	100.0	4	0.22
	2	None	None	None	Segm.	0	19	0.0	100.0	6	0.61
	3	None	None	None	Segm.	0	23	0.0	100.0	5	0.42
*10	1	None	None	None	Whole	0	23	0.0	100.0	4	0.14
	2	None	None	None	Segm.	0	21	0.0	100.0	4	0.24
	3	None	None	None	Segm.	0	20	0.0	100.0	4	0.14

*Seeds coated with glue.

row in both of these flats was planted with whole seeds and the remaining two rows with segmented seeds.

The plants were grown after emergence approximately 1 month. Regular readings of healthy and diseased seedlings were made. At harvest time final readings of healthy and diseased seedlings were made, and the plants were weighed and an average weight per plant was calculated.

Results.—The results of this experiment are given in table 5. Plants grown from all treated seeds in the first six flats had a very high amount of seedling disease. Practically all seedlings were diseased. The height of the tops of these plants varied between 4 and 6 cm. and the weight between 0.25 and 1.25 grams.

Plants grown from untreated beet seeds planted in soil fertilized with nitrogen and phosphorus (flat 7) had a moderate amount of seedling disease. On an average, the plants grown from segmented seeds had less seedling disease than those grown from whole seeds. The height of the tops of these plants varied between 14 and 15 cm. and the weight between 3.03 and 4.16 grams per plant.

Plants grown from untreated whole beet seeds planted in the soil with complete fertilization (flat 8) had a moderate amount of seedling disease and plants grown from segmented seeds in the same soil had only a small amount of disease. The height of the tops of these plants varied between 16 and 18 cm. and the weight between 4.52 and 6.41 grams per plant.

The plants grown in both check flats (9and 10) were all diseased. The height of the tops of these plants was between 4 and 6 cm. and the weight between 0.14 and 0.61 gram per plant.

This experiment presents some evidence that plants which are grown from whole seeds may have more seedling disease than those grown from segmented seeds. The experiment was repeated with similar results.

Conclusion.—These results show conclusively that sodium nitrate and treble superphosphate applied to the surface of sugar beet seeds fail to produce a beneficial effect either on the reduction of seedling diseases or on the promotion of more rapid development of beet seedlings. Plants grown from untreated beet seeds in soil fertilized with complete fertilizers had only a small amount of seedling disease. The tops of these plants were about three times taller and the weights several times greater than those of the plants grown from treated seeds in unfertilized soil. Adequate and properly balanced fertilization of a soil is much more important in control of seedling diseases of beets than coating of seeds with different mineral fertilizers.

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Seed Treatment Dosage Rate Studies on the Control of Damping-off of Sugar Beets[1]

JOHN O. GASKILL and W. A. KREUTZER[2]

The work reported herein covers 3 years of experimental field work on the control of damping-off of sugar beet seedlings. These studies were conducted in 1943, 1944, and 1945 both at Fort Collins and Ault, Colo. Fungicides included in part or all of the tests conducted were Arasan (50-percent tetramethylthiuramdisulfide), Spergon (98-percent tetrachloroparabenzoquinone), New Improved Ceresan (5-percent ethyl mercury phosphate), Yellow Cuprocide (93-percent yellow cuprous oxide), 2-percent Ceresan (2-percent ethyl mercury chloride), and DuPont 1452-F (7.7-percent ethyl mercury p-toluene sulfonanilide).

In 1943 the tests were conducted using only segmented seed, whereas both segmented and whole seed were used in the 1944 and 1945 trials. Randomized-block design was used in all field tests, with 1-row, 18-foot plots, each planted with 2 grams of seed (approximately 6.5 pounds per acre) exclusive of treating compounds. Seed was planted in late spring, and seedling counts were made approximately 3 to 4 weeks after planting. Laboratory determination of the casual agent or agents of damping-off was made for each year's study in each field used.

Experimental Results—1943

In 1943 two field experiments were conducted. Dust fungicides tested were Arasan, Spergon, Yellow Cuprocide, and New Improved Ceresan. The results of this study are given in table 1.

The seedling stand obtained for each fungicidal treatment in each field exceeded that of the check by a highly significant[3] figure. In the Ault field, Yellow Cuprocide and the 5-ounce and 8-ounce applications of New Improved Ceresan were significantly better than the non-metallic treatments, Arasan and Spergon. However, at Fort Collins, Arasan was significantly better than Yellow Cuprocide and the 8-ounce dosage of New Improved Ceresan. Comparison of the stands obtained for the three dosages of New Improved Ceresan shows that the 3-ounce rate was definitely inferior to the 5-ounce and 8-ounce

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[3]Where "highly significant" is used, reference is made to the 1-percent level of signficance (odds 99:1). "Significant" refers to the 5-percent level of significance (odds 19:1).

Table 1.—Comparison of seedling stands obtained from treated and untreated segmented sugar beet seed, Ault and Fort Collins, Colo., in 1943. Results are presented as six-plot averages for each location.

Fungicide		Ave. no. of living seedlings per plot		
Kind	Dosage per 100 pounds of seed	Ault (potato land)	Fort Collins (alfalfa land)	Average
	ounces	no.	no.	no.
Arasan	12	50.7	99.8	69.6
Spergon	32	53.5	85.7	69.6
New Improved Ceresan	3	50.7	87.0	68.8
	5	68.3	105.3	86.8
	8	103.3	84.0	93.7
Yellow Cuprocide	12	98.8	84.5	91.7
Check (no treatment)	....	33.3	56.2	44.8
Difference required for significance:				
Odds 19:1		12.9	12.6	
Odds 99:1		17.1	16.7	

rates in the Ault field. Of the latter two, the 8-ounce dosage was decidedly better at Ault and 5-ounce dosage was much better at Fort Collins, the differences in each case being highly significant.

Isolations from seedlings showing both post- and pre-emergence damping-off, made at 3-day intervals during the period when the disease was most prevalent, indicated that a species of *Pythium* was primarily responsible for damping-off. This organism later was found to be referable to *Pythium ultimum*.

Experimental Results—1944

In 1944 the study was expanded to include three dosage rates for each of four fungicides. Further, in contrast to the 1943 trials, both whole and segmented seed were used. Field tests again were conducted both in the vicinities of Ault and Fort Collins, Colo. The results of these experiments are shown in table 2.

Since the interactions between fungicidal treatments and kinds of seed were not significant, reference will be made only to the average stand obtained for each treatment in the respective fields. At Ault only two treatments were significantly superior to the check in seedling stand: namely, the 8-ounce application of New Improved Ceresan and the 16-ounce dosage of Arasan.

Table 2.—Summary of seedling stands obtained in two sugar beet seed treatment experiments, Ault and Fort Collins, Colo., 1944; basic results given as four-plot averages.

Fungicide		Average number of living seedlings per plot						
		Ault (potato land)			Fort Collins (corn land)			Average Ault and Fort Collins
Kind	Dosage per 100 pounds of seed	Whole seed	Segmented seed	Average	Whole seed	Segmented seed	Average	
	ounces	no.	no.	no.	no.	no.	no.	no.
Arasan	8	57.8	57.8	57.8	112.3	124.8	118.5	88.1
	12	49.3	58.0	53.6	132.5	134.5	133.5	93.6
	16	74.0	57.5	65.8	130.5	147.3	138.9	102.3
New Improved Ceresan	5	50.3	65.3	62.3	123.5	143.5	133.5	97.9
	6.5	65.5	55.8	60.6	143.8	143.8	143.8	102.2
	8	72.8	64.0	68.4	145.8	145.8	145.8	107.1
Du Pont 1452-F	5	52.5	64.0	58.3	151.0	141.3	146.1	102.2
	6.5	56.8	53.3	55.0	139.0	147.3	143.1	99.1
	8	70.3	54.3	62.3	141.3	137.3	139.3	100.8
Yellow Cuprocide	8	61.8	62.8	62.3	110.8	127.0	118.9	90.6
	12	59.0	44.3	51.6	113.5	134.5	124.0	87.8
	16	48.0	58.8	53.4	130.8	125.0	127.9	90.6
Check (no treatment)		49.5	48.5	49.0	101.5	80.8	91.1	70.1
Difference required for significance:								
Odds 19:1		18.9	18.9	13.4*	23.0	23.0	16.3*	
Odds 99:1		25.1	25.1	17.7*	30.5	30.5	21.6*	

*Interactions between fungicidal treatments and kinds of seed were not significant.

At Fort Collins the stand obtained for each dosage of each of the four fungicides exceeded that of the control by a highly significant figure. In comparing the different dosage rates for each separate fungicide, in only one case was a significant difference shown. The 16-ounce dosage of Arasan was significantly superior to the 8-ounce dosage.

Ignoring detailed comparisons for both the Ault and Fort Collins tests, aside from the lightest dosage of Arasan which appeared to be inadequate, in general there were relatively small differences between the stands obtained from seed treated with Arasan, New Improved Ceresan, and Du Pont 1452-F. The stands obtained for Yellow Cuprocide, especially in the Fort Collins test, tended to be lower than those obtained for the other three fungicides.

Isolations again were made in 1944 from affected seedlings, and for the second year *Pythium ultimum* appeared to be the principal damping-off agent. Cultures of *Fusarium* spp. commonly were obtained, especially in isolations from Fort Collins material.

Experimental Results—1945

In 1945 a more detailed dosage-rate study was conducted at Fort Collins and Ault, and for the second year both whole and segmented seed were included in the trials. Five fungicides were used in the tests, each at four different rates of dosage. The results of these tests are given in table 3.

Table 3.—Summary of seedling stands obtained in two sugar beet seed treatment experiments, Ault and Fort Collins, Colo., 1945; basic results given as five-plot averages.

Fungicide		Average number of living seedlings per plot						
		Ault (onion land)			Fort Collins (beet land)			Average Ault and Fort Collins
Kind	Dosage per 100 pounds of seed	Whole seed	Segmented seed	Average	Whole seed	Segmented seed	Average	
	ounces	no.	no.	no.	no.	no.	no.	no.
Arasan	8	64.2	55.0	59.6	41.6	45.0	43.3	51.5
	16	75.0	59.6	67.3	50.0	47.0	48.5	57.9
	24	68.4	64.6	66.5	38.6	41.2	39.9	53.2
	32	75.8	71.8	73.8	50.0	44.2	47.1	60.5
Spergon*	32	33.2	43.2	38.2	29.0	34.2	31.6	34.9
	80	43.4	52.8	48.1	26.8	37.8	32.3	40.2
	128	46.8	57.0	51.9	27.8	32.2	30.0	41.0
	176	37.6	51.4	44.5	34.2	40.0	37.1	40.8
New Improved Ceresan	5	59.8	60.0	59.9	43.2	39.8	41.5	50.7
	8	62.4	58.8	60.6	44.0	44.8	44.4	52.5
	11	70.6	55.4	63.0	43.4	31.6	37.5	50.3
	14	70.4	58.2	64.3	44.2	28.8	36.5	50.4
2-percent Ceresan**	12.7	71.4	73.0	72.2	37.4	42.6	40.0	56.1
	20.3	67.4	72.0	69.7	47.0	36.2	41.6	55.7
	27.9	72.2	68.6	70.4	50.6	45.0	47.8	59.1
	35.5	77.6	70.6	74.1	43.6	38.4	41.0	57.6
Yellow Cuprocide	8	50.2	47.8	49.0	44.0	49.4	46.7	47.9
	16	60.6	55.2	62.4	55.4	44.0	49.7	56.1
	24	64.0	59.6	61.8	45.8	33.2	39.5	50.7
	32	77.6	59.4	68.5	35.6	45.8	40.7	54.6
Check (no treatment)		23.0	20.8	21.9	28.6	33.0	30.8	26.4
Difference required for significance:								
Odds 19:1		12.3	12.3	†	13.2	13.2	9.3‡	
Odds 99:1		16.2	16.2	†	17.4	17.4	12.3‡	

*Weighings showed that approximately two-thirds of the extremely heavy 176-ounce application of Spergon adhered to the seed at treating time. The percentage of this dust adhering to the seed was progressively higher with lighter applications.

**The dosage rates used for 2-percent Ceresan were equivalent in mercury content to those used for New Improved Ceresan.

†Interaction between fungicidal treatments and kinds of seed was significant.

‡Interaction between fungicidal treatments and kinds of seed was not significant.

With reference to the Ault data shown in table 3, the whole and segmented seed averages were considered separately because in this particular field trial the interaction between fungicidal treatments and type of seed used was significant. The results from both whole and segmented seed show that all fungicidal treatments were much superior to their respective controls (1-percent level of significance) with the exception of the 32-ounce and 176-ounce rates of Spergon on whole seed. In comparing dosage rates for the respective fungicides, some significant differences were shown by the Arasan, Spergon, and Yellow Cuprocide series. With segmented seed, the 32-ounce rate of Arasan gave much better results than the 8-ounce rate—a highly significant difference. A similar trend, although non-significant, is shown for whole seed. With both whole and segmented seed, the 128-ounce rate of Spergon was significantly better than the 32-ounce rate. With whole seed, the 16-, 24-, and 32-ounce rates of Yellow Cuprocide were significantly better than the 8-ounce rate. The difference was particularly striking and highly significant in the case of the 32-ounce rate. A similar trend, although non-significant was shown by the segmented seed. With both whole and segmented seed, the differences resulting from the use of varying dosage rates of New Improved Ceresan and 2-percent Ceresan, respectively, were not significant.

In the Fort Collins field plots, the interaction between fungicidal treatments and kinds of seed was not significant, and consequently reference will be made only to the treatment averages. Highly significant improvement in stand over that of the control was shown by each of the following: the 8-, 16-, and 32-ounce rates of Arasan, the 8-ounce rate of New Improved Ceresan, the 27.9-ounce rate of 2-percent Ceresan, and the 8-and 16-ounce rates of Yellow Cuprocide. The stand differences shown between rates of dosage for any one material were non-significant with the exception of Yellow Cuprocide. In this latter case the 16-ounce rate gave a significantly better stand than the 24-ounce rate, which result conflicts with the trend shown for the Ault field plots.

Laboratory isolations from affected seedlings again indicated that *Pythium ultimum* was the principal agent of damping-off in both the Fort Collins and Ault fields. At Fort Collins a species of *Phytophthora* also was commonly obtained in early platings. *Phytophthora* only rarely appeared in the Ault isolations. As in the 1944 tests, *Fusarium* spp. frequently were obtained from both the Ault and Fort Collins material.

Table 4 is a summary of all stand data obtained in the 3 years' experiments: 1943, 1944, and 1945. Although various significant interactions prevent comparisons on the basis of statistical odds within

Table 4.—Summary of seedling stands obtained in sugar beet seed treatment experiments, Ault and Fort Collins, Colo., 1943-1945.

Fungicide		Average no. of living seedlings per plot									
		1943		1944		1945		2-year average			
Kind	Dosage per 100 pounds of seed	Ault	Fort Collins	Ault	Fort Collins	Ault	Fort Collins	1943 and 1944	1943 and 1945	1944 and 1945	3-year average
	ounces	no.	no.	no.	no.	no.	no.	no.	no.	no.	no.
Number of replications*		6	6	8	8	10	10				
Arasan	8	....	....	57.8	118.5	59.6	43.3	....	....	69.8	....
	12	50.7	99.8	53.6	133.5	....	....	84.4	....	....	....
	16	....	....	65.8	138.9	67.3	48.5	....	....	80.1	....
	24	....	....	....	....	66.5	39.9	....	....	....	....
	32	....	....	....	....	73.8	47.1	....	....	....	....
Spergon	32	53.5	85.7	....	....	38.2	31.6	....	52.3	....	....
	80	....	....	....	....	48.1	32.3	....	....	....	....
	128	....	....	....	....	51.9	30.0	....	....	....	....
	176	....	....	....	....	44.5	37.1	....	....	....	....
New Improved Ceresan	3	50.7	87.0	....	....	....	....	....	....	....	....
	5	68.3	105.3	62.3	133.5	59.9	41.5	92.4	68.8	74.3	78.5
	6.5	....	....	60.6	143.8	....	....	....	....	....	....
	8	103.3	84.0	68.4	145.8	60.6	44.4	100.4	73.1	79.8	84.4
	11	....	....	....	....	63.0	37.5	....	....	....	....
	14	....	....	....	....	64.3	36.5	....	....	....	....
2-percent Ceresan	12.7	....	....	....	....	72.2	40.0	....	....	....	....
	20.3	....	....	....	....	69.7	41.6	....	....	....	....
	27.9	....	....	....	....	70.4	47.8	....	....	....	....
	35.5	....	....	....	....	74.1	41.0	....	....	....	....
Du Pont 1452-F	5	....	....	58.3	146.1	....	....	....	....	....	....
	6.5	....	....	55.0	143.1	....	....	....	....	....	....
	8	....	....	62.3	139.3	....	....	....	....	....	....

Table 4.—Continued.

Yellow Cuprocide	8	....	....	62.3	118.9	49.0	46.7	....	....	69.2	....
	12	98.8	84.5	51.6	124.0	....	....	89.7	....	....	....
	16	....	....	53.4	127.9	62.4	49.7	....	....	73.4	....
	24	....	....	....	....	61.8	39.5	....	....	....	....
	32	....	....	....	....	68.5	40.7	....	....	....	....
Check (no treatment)		33.3	56.2	49.0	91.1	21.9	30.8	57.4	35.6	48.2	47.1
Difference required for significance:											
Odds 19:1		12.9	12.6	13.4	16.3	**	9.3				
Odds 99:1		17.1	16.7	17.7	21.6	**	12.3				

*Results obtained for whole and segmented seed were combined for the years 1944 and 1945, respectively; 1943 results were obtained from segmented seed only.

**Interaction between fungicidal treatments and kinds of seed was significant in the Ault experiment in 1945 but was not significant in any other test.

certain columns of this table, it is presented as an aid in studying the results.

Summary and Conclusions

Two replicated sugar beet seed treatment experiments were conducted in the vicinities of Ault and Fort Collins, Colo., in each of the years 1943, 1944, and 1945. A total of six dust fungicides were employed, though not all were used in any 1 year. Varying dosages were applied in most cases. Only segmented seed was used in 1943, while both whole and segmented types of seed were used in 1944 and 1945. *Pythium ultimum* was considered the chief cause of damping-off in each of the six experiments. A species of *Phytophthora* apparently played a relatively minor role in one test, and species of *Fusarium* were isolated rather commonly in several tests.

Each of the following fungicides was quite effective in improving seedling survival in fields where damping-off was an important factor: Arasan, New Improved Ceresan, 2-percent Ceresan, Du Pont 1452-F, and Yellow Cuprocide. With adequate dosages there was relatively little difference in the effectiveness of these five dusts. Spergon, although used over a wide range of dosages, failed to give seedling stands equal to those obtained from adequate applications of any of the other dusts.

The evidence obtained from the six experiments suggests the following tentative conclusions as to minimum dosages required for satisfactory control of damping-off under the conditions of these experiments:

Fungicide	Ounces per 100 pounds of seed
Arasan	16
New Improved Ceresan	6[a]
2-percent Ceresan	12.7
Du Pont 1452-F	5
Yellow Cuprocide	16

[a]The 2-year and 3-year averages presented in table 4 show appreciably higher stands for 8 ounces than for 5 ounces. However, the striking contradition in Fort Collins data for 1943 emphasizes the need for caution with respect to the 8-ounce rate.

In the commercial treating, a somewhat higher percentage of dust possibly would adhere to the seed than occurred in the treating of small lots used in these experiments. Therefore in commercial practice, slightly lower minimum standards might be preferable to those listed above.

Seed Treatment Tests, 1944 and 1945

ALBERT ISAKSSON, H. E. BREWBAKER, and H. L. BUSH[1]

A satisfactory stand at thinning time is one of the chief factors in sucessful beet growing. Therefore, protection against damage by organisms involved in either pre- or post-emergence mortality is very important, and the use of segmented seed on a large scale, resulting in a substantially reduced initial stand, greatly increases the importance of this protection.

A considerable amount of data now available indicate that a major part, or sometimes practically all, of the fungus damage done to the seedling stand may take the form of pre-emergence mortality. It has been shown that certain forms of seed treatments may be effective against this form of disease, and it may also be possible to obtain satisfactory protection against post-emergence mortality by seed treatments. From the practical point of view it would then appear especially important to investigate the possibilities of devising some seed treatment which would be both effective and harmless when used generally in a standardized form.

The seed treatment tests conducted by the Longmont Experiment Station during the 1944 and 1945 seasons consisted of two different series; (1) relatively localized, but of a somewhat complex nature, and (2) comprising fewer treatments and replications but with larger individual plots and designed to reach all factory districts.

Seed and Seed Treatments Used

Segmented seed as furnished the farmers was used, but it was run through a small fanning machine for removal of dust and small particles of trash which otherwise would have interfered with the uniformity of the portions of seed prepared for the individual plots.

The number of treatments and their composition are reported in tables 1 and 2 for test A and in table 3 for test B in 1945. The treatments constituting test B for 1944, which is not reported in detail, were as follows:

1. New Improved (N.I.) Ceresan 4 ounces
2. Fume phosphate 12 ounces + N.I. Ceresan 4 ounces
3. Fume phosphate 20 pounds
4. Fume phosphate 20 pounds + N.I. Ceresan 4 ounces
5. Yellow Cuprocide 12 ounces

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[1]Plant Pathologist, Director, and Statistician-Agronomist, respectively, Experiment Station, Great Western Sugar Company, Longmont, Colo.

6. Fume phosphate 20 pounds + Yellow Cuprocide 12 ounces
7. Fume phosphate 20 pounds + Yellow Cuprocide 12 ounces + N.I. Ceresan 4 ounces
8. Untreated check

Amounts of substances applied are given in terms of pounds or ounces per 100 pounds of seed if not otherwise stated.

In all cases in which it was practical the treatments were applied as dry dust treatments. The applications of 10 pounds or more of fume phospahte were added to the seed immediately following wetting of the seed with an amount of water representing 16 to 18 percent of the weight of air dry seed and phosphate combined. Thorough air drying followed the application.

The nitrogen compounds were applied in aqueous solution. When they were combined with heavy phosphate applications, the same wetting served for attaching the phosphate.

The Dow No. 6 material was in flake form and being water-soluble was applied in the same manner as the nitrogen compounds.

After air drying of seed which had required wetting, any dust treatment called for was applied in the usual manner. Dry dusts, when more than one were to be used, were mixed well before they were applied to the seed.

Test A

Materials and Methods.—In both 1944 and 1945 seasons these test series were conducted directly from the Longmont Experiment Station with all the individual tests located within a radius of 15 miles of the Station. These tests were placed in farmers' fields with the exception of one on the Experiment Station farm in 1944. There were 13 tests laid out and carried through in 1944 and 14 laid out with 11 carried through in 1945.

The test scheme used for the two series A with individual tests comprising 25 treatments, including an untreated check, was a triple lattice design with 2 replicates of each group, or a total of 6 replicates. Each plot consisted of one row, 29 feet in length.

The amount of net seed used per plot was the same within season for either of the two seasons and was calculated to give a potential stand of 270 seedlings per plot in 1944 and 300 seedlings per plot in 1945.

Seedling counts of the entire plot length made at or shortly before the ideal thinning time were the basis for comparison in determining the effectiveness of the various treatments. The test located

at the Experiment Station farm in 1944 was counted twice, with 8 days between counts to determine the extent of post-emergence damping-off.

Results for 1944.—The results of test A for 1944 are summarized statistically, on the basis of average plot values in percent of check for the 6 replicates used, in table 1.

New Improved Ceresan and Arasan, alone or in combinations, seemed to be leading in effectiveness. The three different amounts of N.I. Ceresan alone averaged very well but did not quite reach the value shown by 12 ounces of Arasan alone. Differences from the check in favor of the latter treatment proved highly significant (LSD 1-percent point) at two locations, and significant (LSD 5-percent point) at one location. N.I. Ceresan together with 12 ounces of fume phosphate was no better than N.I. Ceresan alone. In location VIII 8 ounces of N.I. Ceresan alone may have been an overdose, since the value was significantly lower than the check. The 6-ounce application of N.I. Ceresan alone appeared somewhat superior to both 4 and 8 ounces, while for Arasan the largest application (18 ounces) proved best.

Yellow Cuprocide alone (12 ounces) was practically equal in effect to the combination of 4 ounces of N.I. Ceresan plus 12 ounces of fume phosphate and also the combination of 12 ounces of yellow cuprocide with 12 ounces of Arasan.

"1452F", a Du Pont mercurial, averaged slightly better than the check in the amount used (5 ounces).

Dow No. 5 and No. 6 averaged fairly close to the check, and since they have been practically discontinued for beet trials by the manufacturers they are not further discussed here.

Nitrogen, as applied here, never appeared beneficial but was somewhat detrimental on the average and considerably so in a few cases.

Fume phosphate at a relatively low rate in combination with N.I. Ceresan is discussed above. In larger quantities, 10, 30, and 50 pounds of fume phosphate alone consistently proved to be either the poorest treatment or nearly so, and together with the combination nitrogen-N.I. Ceresan-fume phosphate averaged the poorest of all the treatments within the entire series. This was not entirely in agreement with the results obtained in the 1943 tests (*1*)[2], in which a 10-pound application of fume phosphate resulted in a certain improvement over the check, as the average of tests conducted on six fields, while a significant reduction was noted in one location. The

[2]Italic numbers in parentheses refer to literature cited.

Table 1.—Average number of seedlings per plot in percentage of untreated check for seed treatment test. Longmont district, 1944.

No.	Treatment per 100 pounds seed[c]	LOCATION													
		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	Mean
1.	N. I. Cer. 4 oz.	114	101	105	125*	108	108	107	96	148**	99	87	90	115	107.2
2.	N. I. Cer. 6 oz.	104	105	113	136**	119	105	103	88	151**	91	95	101	134	111.2
3.	N. I. Cer. 8 oz.	102	111	86	137**	107	105	95	85°	129*	97	85	83	101	109.5
4.	Y. Cup. 12 oz.	105	113	116	120*	100	102	106	86	130*	91	100	103	99	105.5
5.	Ara. 12 oz.	113	115	132*	131**	112	105	111	92	125	102	83	107	152**	113.8
6.	F. P. 10 lbs.	71°°	77°	75	27°°	52°°	72°°	100	84°	34°°	82	82	89	100	72.7
7.	F. P. 30 lbs.	69°°	58°°	84	21°°	47°°	56°°	85	64°°	27°°	91	69°	81	81	64.1
8.	F. P. 50 lbs.	71°°	56°°	84	31°°	27°°	63°°	93	74°°	22°°	80	57°°	71°	75	61.8
9.	N. I. Cer. 4 oz. + F. P. 12 oz.	107	99	108	132**	99	99	111	87	135*	103	109	103	97	106.8
10.	N. I. Cer. 4 oz. + F. P. 10 lbs.	102	115	107	110	94	108	97	84°	106	76°	90	85	94	97.5
11.	N. I. Cer. 4 oz. + F. P. 30 lbs.	94	91	114	108	81	99	99	85°	121	80	90[a]	76°	88	86.7
12.	N. I. Cer. 4 oz. + F. P. 50 lbs.	93	82	121	127**	78	101	103	92	123	81	75	62°°	90	94.5
13.	Ara. 12 oz. + F. P. 10 lbs.	103	107	106	103	102	107	108	84°	126	92	85	91	118	102.5
14.	Ara. 12 oz. + F. P. 30 lbs.	121*	96	98	125*	101	110	92	82°	126	102	80	92	90	101.2
15.	Ara. 12 oz. + F. P. 50 lbs.	113	86	121	131**	107	108	97	84°	148**	72°°	71°	87	114	103.0
16.	N. I. Cer. 4 oz. + Y. Cup. 12 oz.	108	107	115	128**	108	111	101	92	157**	98[a]	87	69°	123	108.0
17.	Ara. 12 oz. + Y. Cup. 12 oz.	102	114	112	98	104	104	116	92	115	84	101	110	122	105.7
18.	Dow No. 5, 5 oz.	90	114	86	92	69°	102	108	77°°	88	108	89	96	103	94.0
19.	Dow No. 6, 5 oz.	108	109	98	109	89	96	106	78°°	132*	91	82	91	113	100.2
20.	"1452F" 5 oz.	119*	117	92	125*	105	91	113	79°°	141**	94	97	84	108	102.5
21.	N only[b]	80°	89	101	65°°	60°°	91	111	91[a]	58°°	89	80	72°	105	76.3
22.	N + N. I. Cer. 4 oz.[b]	97	100	120	114	87	113	104	83°	106	82	87	84	86	97.2

Table 1.– Continued.

23.	N + N. I. Cer. 4 oz. + F. P. 30 lbs.[b]	93	75°	103	42°°	31°°	77°°	100	73°°	58°°	80	73°	60°°	80	72.7
24.	N + Ara. 4 oz. + F. P. 30 lbs.[b]	93	105	94	105	109	98	107	87	115	87	89	90	110	99.2
25.	Untreated check	100	100	100	100	100	100	100	100	100	100	100	100	100	100.0
General Mean		98.9	97.7	103.6	101.7	87.8	97.2	102.9	84.8	108.8	90.1	85.9	87.1	103.9	96.2
CV (percentage)		15.49	18.51	25.47	16.83	27.71	15.97	15.36	15.59	22.89	20.84	27.78	24.01	33.23	.....
LSD 5-percent point		17	21	30	20	28	18	18	15	28	21	27	24	39	....
LSD 1-percent point		23	27	40	26	37	23	24	20	38	28	36	32	52	....
Mean No. seedlings per plot		146.0	140.3	106.5	145.0	84.9	165.4	143.0	168.6	86.5	142.3	52.8	97.3	62.6	....

* and ** Significantly better than check at the 5-percent and 1-percent points, respectively.

° and °° Significantly poorer than check at the 5-percent and 1-percent points, respectively.

[a] One missing plot value calculated.

[b] Nitrogen (N) applied 5-percent on weight of seed in 50-50 mixture of $(NH_4)_2SO_4$ + $NaNO_3$ dissolved in water (20 percent on seed). subsequent air drying.

[c] Abbreviations used: N. I. Cer.—Ceresan, New Improved. Y. Cup.—Yellow Cuprocide. Ara.—Arasan. F. P.—Fume phosphate.

generally reducing effect noted for the heavy phosphate applications was diminished but not altogether offset by the addition of Arasan or N.I. Ceresan, when the comparison was made with these fungicides alone. Combinations of large amount of phosphate with Arasan appeared generally superior to such combinations with N.I. Ceresan. The addition of nitrogen to the heavy phosphate-N.I. Ceresan combination resulted in a material lowering of the average, while this addition to the heavy phosphate-Arasan combination did not appreciably lower the value.

General Observations.—The season of 1944 was characterized by a rather general freedom from seedling disease and this condition no doubt was reflected in the relatively high position of the check and in the fact that in many locations even the better treatments failed to give significant improvements. Very great differences in response to treatments between locations are noted. The results apply almost entirely to pre-emergence mortality, since no damping-off of any consequence was observed after emergence.

Results for 1945.—Chiefly pre-emergence mortality was involved in the reduction of stand by diseases in 1945 also. A summary of the results of test A expressed as mean number of seedlings in percent of check is presented in table 2.

N.I. Ceresan alone was one of the best treatments, and the results were somewhat in favor of the 4-ounce application. The 8-ounce application was significantly poorer than the check in one location (XI).

Two of the Arasan treatments were several points below N.I. Ceresan as used alone. A rise in effect with increased application was consistent through the three treatments. A highly significant reduction was associated with the 6-ounce application in the same location (XI) in which one N.I. Ceresan treatment was highly significantly reduced.

When N.I. Ceresan or Arasan was combined with fume phosphate, there was, as in 1944, an apparent trend in favor of Arasan. Trends relative to dosage were not consistent. The N.I. Ceresan-phosphate combinations averaged short of N.I. Ceresan alone in effect, while the Arasan-fume phosphate combinations averaged better than either Arasan or N.I. Ceresan alone. The combination of 4 ounces of N.I. Ceresan and 12 ounces of fume phosphate averaged lower than either of the N.I. Ceresan treatments.

Du Pont "1452F" alone averaged essentially the same as Arasan alone. An improvement with increased dosage was noted, but

Table 2.—Average number of seedlings per plot in percentage of untreated check

Table 2.—Average number of seedlings per plot in percentage of untreated check for seed treatment test. Longmont district, 1945.

No.	Treatment per 100 pounds seed[d]	LOCATION I	II	III	IV	V	VI	VII[c]	VIII	IX	X	XI	Mean
1.	N. I. Cer. 4 oz.	124*	105	157**	102[a]	94	104	223*	112**	179**	121	106	129.7
2.	N. I. Cer. 6 oz.	111	107	141*	95[b]	104[a]	106*	205	142**	164**	106	87[a]	124.4
3.	N. I. Cer. 8 oz.	112	112**	136*	104	108	113**	207	161**	163**	99	80°	126.8
4.	Arasan 6 oz.	108	110*	110	103[a]	114	124**	205	108	117	113	77[b]°	117.2
5.	Arasan 12 oz.	117	113**	137*	116[b]	94	99	182	130**	131*	108	98[b]	120.5
6.	Arasan 18 oz.	106	108	125	98	105	129**	223*	124**	157**	128*	93	126.9
7.	"1452F" 4 oz.	122*	108	164**	87	95[a]	100	153	120**	134*	98	103	116.7
8.	"1452F" 6 oz.	130**	103	127	99	111	123**	162	124**	157**	118	92	122.4
9.	"1452F" 8 oz.	111	106	141*	85	103	104	272**	122**	150**	106	77°°	125.2
10.	Y. Cup. 12 oz.	122*	111**	157**	100	110	115**	178	116**	129	99	88[a]	120.5
11.	K-611 12 oz.	106	103	107	89	103	106*	272**	89°	150**	114	73[a]°°	119.3
12.	9-B 12 oz.	121*	103	130	105[a]	93	92°°	152	118**	98	96	113	111.0
13.	F. P. 20 lbs.	88	89°	44[a]°°	83	89	84[b]°°	90	58°°	89	70°°	29°°	71.2
14.	N. I. Cer. 4 oz. + F. P. 12 oz.	113	119**	122	101	108	104	200	107	155**	116	91[b]	121.5
15.	N. I. Cer. 6 oz. + F. P. 20 lbs.	95	105	146**	93	106	119**	193	128**	167**	97	88[a]	121.5
16.	N. I. Cer. 8 oz. + F. P. 20 lbs.	105	101	138*	93	99	118**	273**	129**	175**	103	91	129.5
17.	Ara. 6 oz. + F. P. 20 lbs.	119	106	128	115	116	107*	247*	115**	118	111	86	124.4
18.	Ara. 12 oz. + F. P. 20 lbs.	126*	107	121	103	106	126**	292**	141**	133*	125*	96	134.2
19.	Ara. 18 oz. + F. P. 20 lbs.	123*	110*	121	109	111	131**	258**	139**	127	102	97	129.8
20.	N. I. Cer. 6 oz. + Y. Cup 8 oz.	112	115**	123	105	94	122**	182	112**	141*	110	93	119.0
21.	N. I. Cer. 6 oz. + Y. Cup. 12 oz.	118	113**	146**	102	105	127**	228*	104	159**	110	82°	126.7
22.	Ara. 12 oz. + Y. Cup. 8 oz.	129**	106	127	105	115	95	177	116**	137*	103	84	117.6
23.	Ara. 12 oz. + Y. Cup 12 oz.	111	112**	120	98	117	105	115	129**	146**	114	91	114.4
24.	"1452F" 6 oz. + Y. Cup. 12 oz.	119	111*	124	109	118	117**	277**	128**	153**	138**	92	135.1
25.	Untreated check	100	100	100	100	100[a]	100	100	100	100	100	100	100.0
General mean		113.9	107.3	127.7	100.0	104.7	110.8	201.4	118.9	141.2	108.2	88.3	120.2
CV (percentage)		16.38	7.05	21.61	16.87	19.17	4.62	46.63	6.75	19.28	17.51	17.01	.....
LSD 5-percent point		21	9	32	No Sig.	No Sig.	6	118	9	31	22	18	.....
LSD 1-percent point		28	11	42	No Sig.	No Sig.	8	156	12	41	29	23	.....
Mean No. seedlings per plot		124.0	256.6	100.2	170.2	120.3	87.4	24.2	36.5	104.6	101.4	143.2	.....

* and ** Significantly better than check at the 5-percent and 1-percent points, respectively.

° and °° Significantly poorer than check at the 5-percent and 1-percent points, respectively.

[a] One missing plot value calculated.

[b] Two missing plot values calculated.

[c] Five replications.

[d] Abbreviations used: N. I. Cer.—Ceresan, New Improved. Y. Cup.—Yellow Cuprocide Ara.—Arasan F. P.—Fume phosphate

the 8-ounce application resulted in a highly significant reduction in location XI, referred to for similar performances of N.I. Ceresan and Arasan. "1452F" with Yellow Cuprocide in treatment 24 ranked the highest of all treatments in this series.

Yellow Cuprocide 12 ounces fell well in line with treatment 14 (4 ounces Ceresan and 12 ounces fume phosphate) and with the general mean of all treatments.

Dow Company products K-611 and 9-B (copper and zinc salts, respectively, of 2, 4, 5 trichlorophenol) were used in 12-ounce applications. Significant differences from the check for both increases and reductions were noted in the results obtained. K-611 averaged the higher of these but performed perhaps more irregularly than 9-B.

Again, as in 1944, very great differences existed between locations in their response to treatments.

Test B

Materials and Methods.—In each factory district three separate fields were chosen in which seedling disease was considered reasonably likely to occur. One test was placed on each of these fields. Each test included seven different treatments together with one untreated check, or eight treatments in all, and these were replicated three times in randomized arrangement using one-row plots. A different randomization was used for each of the three fields. For each treatment the results for pre-thinning seedling counts made on 8 strips (1944) or 10 strips (1945) of row of 100 inches length per plot served as a basis for calculation of the stand obtained per unit of seed. The figure representing the total count for the three replications was divided by the weight of seed (grams or fractions of a pound) reported used, and the values thus obtained were converted into percentages of the check. Of these tests 35 were completed in 1944 and 40 in 1945. In 1944, however, the data obtained appeared very erratic and were not considered as warranting statistical analysis, while for the 1945 data significant differences were obtained between treatments from 16 fields distributed on 11 factory districts.

Results for 1944.—Although the test was not analyzed statistically, the following facts are presented as a matter of record: Treatment 2, a combination of 12 ounces of fume phosphate and 4 ounces of N.I. Ceresan, averaged the highest (112.8), followed by treatment 5, Yellow Cuprocide 12 ounces (106.0). Treatment 3, fume phosphate 20 pounds, averaged the lowest (85.6). When the fume phosphate was buffered by N.I. Ceresan (treatments 4 and 7) the average stand differed but little from the check or from N.I. Ceresan alone (treatment 1); when buffered by Yellow Cuprocide (treatment 6),

Table 3.—Seedling stand obtained per unit of seed in percentage of check. All-factory seed treatment test, 1945.

No.	Treatment per 100 lb. seed[b]	Greeley 3	Windsor 3	Longmont 1[a]	Longmont 3	Brighton 2	Brighton 3	Ft. Lupton 1
1.	F. P. 12 oz. + Cer. 4 oz.	104	130*	97	110	87	121**	78°°
2.	N. I. Cer. 6 oz.	79°	122*	110	97	73	117*	67°°
3.	F. P. 20 lbs. + N. I. Cer. 6 oz.	Lost	142*	130	127**	123	138**	84°
4.	Y. Cup. 12 oz.	118*	122*	146*	112	58°	132**	84°
5.	"1452F" 6 oz.	90	116	115	96	39°°	112	78°°
6.	N. I. Cer. 4 oz. + Y. Cup. 12 oz.	111	134*	196**	102	112	119*	76°°
7.	Arasan 12 oz.	114	127*	267**	126**	113	129**	86°
8.	Check	100	100	100	100	100	100	100
General Mean		102.3	124.1	145.1	108.8	88.1	121.0	81.6
CV (percentage)		9.46	9.53	9.92	7.33	21.92	7.15	8.83
LSD 5-percent point		17	21	34	14	34	15	13
LSD 1-percent point		24	Not sig.	50	19	47	21	18

Table 3.—Continued

Sterling 2	Brush 2	Ft. Morgan 2	Ft. Morgan 3	Gering 1	Gering 3	Bayard 1	Bayard 3	Minatare 3	Mean
140**	118*	108	94	100	146**	122*	157*	99	113.2*
124**	97	123*	99	105	126	107	116	103	104.1
160**	110	100	80°°	94	107	118*	86	110	113.9*
132**	97	117*	103	115	68°	119*	106	104	108.3*
134**	103	128*	85°	80	166**	111	103	101	103.6
135**	118*	119*	100	122	168**	124*	97	102	120.9*
138**	123*	119*	107	99	143**	110	113	164**	129.9*
100	100	100	100	100	100	100	100	100	100.0
132.9	108.3	114.3	96.0	101.9	128.0	113.9	109.8	110.4	111.7
6.88	8.27	7.89	7.96	12.71	13.51	7.27	12.21	6.64	2.63
16	16	16	13	23	30	15	24	13	5.2
22	Not sig.	Not sig.	19	Not sig.	42	Not sig.	33	18	.. ..

* and ** Significantly better than check at the 5-percent and 1-percent points, respectively.

° and °° Significantly poorer htan check at the 5-percent and 1-percent points, respectively.

[a] Two replications. All other locations three replications.

[b] Abbreviations used:

N. I. Cer.—Ceresan, New Improved
Y. Cup.—Yellow Cuprocide
F. P.—Fume phosphate

some improvement was indicated but the value of the check was not reached.

Results for 1945.—The results of the seedling counts from the 16 locations yielding statistically significant differences between treatments (5-percent and 1-percent points) are presented in table 3.

As in test A, striking differences in response to treatments were found between different locations. In the Fort Lupton test all applications proved either significantly or highly significantly poorer than the check, and in some other locations several treatments ranked very low, sometimes significantly so. At the same time it is true that the general mean of all treatments was considerably higher than the value for the check and that five of the seven treatments used averaged at least significantly better than the check. These facts would seem to indicate presence of disease and benefit from the treatments generally.

Fume phosphate 12 ounces and N.I. Ceresan 4 ounces (treatment 1) averaged slightly better than the general mean and much higher than the check.

N.I. Ceresan 6 ounces (treatment 2) averaged second lowest aside from the check and thus much poorer than the same treatment in test A, especially in 1945.

Fume phosphate 20 pounds and 6 ounces of N.I. Ceresan (treatment 3) at least equalled treatment 1 on the average.

Yellow Cuprocide 12 ounces alone (treatment 4) ranked lower than treatments 1 and 3 but was considerably better than the check.

"1452F" 6 ounces (treatment 5) averaged lowest and not significantly better than the check.

N.I. Ceresan 4 ounces and Yellow Cuprocide 12 ounces (treatment 6) ranked second best, significantly better than any of the treatments preceding.

Arasan alone 12 ounces (treatment 7) proved to be the best treatment in the series.

Summary

1. Two series of tests with seed treatments against seedling diseases in sugar beets were conducted.

2. Very great variations in the effectiveness of various treatments were found to exist between individual fields.

3. In spite of these variations it was observed that the treat-

ments commercially designated N.I. Ceresan and Arasan rather consistently ranked among the very best, while "1452F" and Cuprocide ranked very high, alone or in combinations, with less consistency.

4. Applications of large amounts fume phosphate alone to the seed consistently resulted in reduced seedling counts, while in some instances mixtures of large amounts of fume phosphate and fungicides approached or compared favorably with those fungicides alone in effectiveness.

5. Nitrogen, as used in the test, whether alone or in combination, appeared detrimental in many cases and in no cases statistically beneficial.

6. It is indicated that it will be very difficult to design a universally superior treatment, perhaps because of natural factors out of our control. However, the fact that the top ranking treatments as identified where they have been most effective, and barring some instances of possible overdosage, still in a general way are found associated with the higher or highest seedling counts in locations where treatments prove to be not needed or ineffective, or perhaps detrimental, indicates that it may be possible to approach the goal of a generalized seed treatment to a rather satisfactory degree.

Literature Cited

1. Isaksson, A. and Brewbaker, H. E. Seed Treatment Tests, 1943. Proc. Amer. Soc. Sug. Beet Tech. Regional Meeting, Eastern Slope and Intermountain 5-9. 1944.

Seed Treatment Studies

A. R. Downie[1]

Seed treatment is a standard practice in most of the territories where sugar beets are grown for the American Crystal Sugar Company. New Improved Ceresan is the most popular seed treatment material, especially in the areas where the seed can be planted immediately after treatment.

In 1944 and 1945 seed treatment tests were conducted in several areas, the following treatments being used: Arasan, New Improved Ceresan, Yellow Cuprocide, and Phygon. Four tests were conducted in three different areas of the Rocky Ford Factory, one test each at East Grand Forks, Minn., Grand Island, Neb., and Mason City, Iowa.

Besides the field tests, seed treatment tests in soil obtained from 9 different areas were made in flats in the greenhouse at the Rocky Ford Beet Seed Station.

Field Results in the Rocky Ford Factory Areas

Sheared seed planted at the rate of approximately 4 pounds per acre was used in all experiments. Plots were four rows wide and 50 feet long with no fewer than six replications in any one test.

Table 1 shows the number of beet-containing inches in 100 inches of row. Each number represents a six-plot overage of five 100-inch counts per plot, except in the 1944 test where 10 replications were used.

Table 1.—The number of beet-containing inches per 100 inches of row.

Treatment	Rate	Rocky Ford		Lamar	Center
Arasan	1:100	11.8*	13.3**	11.9	28.6
New Improved Ceresan	6oz:100	10.2	15.8	6.7	21.7
Ceresan	1:100	12.4	15.7	....	....
Cuprocide (Yellow)	1:50	9.5	....	11.6	19.4
Phygon	1:100	....	30.3	....	....
Check	None	12.9	25.0	12.1	22.2
Significant difference (19:1)		1.9	3.6	....	5.35

*1944 results
**1945 results

It is to be noted from table 1 that, in general, seed treatment did not have a beneficial effect in the tests at Rocky Ford. Except in the case of Phygon in the 1945 test, seed treatments tended to give poorer stands than no treatment. The same is true in the Lamar

[1]Plant Pathologist, Beet Seed Operations, American Crystal Sugar Company, Rocky Ford, Colo.

test, and especially so in the case of New Improved Ceresan. The Arasan treatment gave significantly better stands than the check and all other treatments at Center, Colo.

Tests in Other Areas

The results for the East Grand Forks, Grand Island, and Mason City seed treatment tests are given in percent stand after thinning (table 2). Treatments were replicated six times in all three tests. The percent stand was obtained by counting the number of beets in 100 feet of row in each plot and is given as a six-plot average.

Significantly better stands were obtained from all treatments in the East Grand Forks test. New Improved Ceresan was significantly better than Cuprocide and no treatment. In the Grand Island test, although all treatments were higher than check, only Arasan was significantly so. There were no significant differences due to treatment in the Mason City experiment.

Table 2.—Percent stand after thinning.

Treatment	Rate	East Grand Forks	Grand Island	Mason City
Arasan	1:100	88.9	75.3	74.4
New Improved Ceresan	6 oz:100	92.9	70.7	74.4
Ceresan	1:100	....	69.2	....
Cuprocide (Yellow)	1:50	88.1	....	....
Phygon	1:100	....	71.0	75.0
Check		78.1	63.5	78.2
Significant difference (19:1)		4.1	9.9	ns

Greenhouse Tests

In the fall of 1945, soil samples of approximately 200 pounds each were obtained from the following locations: Oxnard, Clarksburg, and American Island Farm, Calif.; Missoula, Mont.; Rocky Ford, Colo.; Lubbock, Texas; Grand Island, Nebr.; and Chaska and East Grand Forks, Minn. Flats containing soil from each of these locations were planted with sheared seed treated with the following materials: Arasan, New Improved Ceresan, Phygon, and non-treated. Each flat contained 4 replications of 20 seeds of each of the 4 treatments or 16 rows per flat. All seeds were planted 5/8 inch deep and 1 inch apart in the row. During the course of the experiment the nightly temperatures varied from 54° to 57° F. The daytime temperature was 70°, only very occasionally going above 80°. Although daily stand counts were taken, only the total seedling stand 17 days after planting is summarized here.

Table 3 gives the analysis of variance data for the experiment.

Table 3.—Analysis of variance.

Variation due to:	D/F	Sums of Squares	Mean Squares	F
Seed treatments	3	753.91	251.30	14.84**
Soils	8	803.63	100.45	5.93**
Blocks	3	51.97	17.32	1.02
Treatments x soils	24	485.15	20.21	1.19
Error	106	1,794.78	16.93	
TOTAL	144	3,889.44		

**Signficant difference at the 99:1 level.

From table 3 it may be seen that there are significant differences between treatments and between soils; however, it is to be noted that the F value for the interaction, treatments x soils is not significant. Therefore it may be stated that for this test there was no significant reversal of reaction of any of the treatments between any two soils. No individual treatment was significantly better in one soil and significantly poorer in another soil.

In table 4 are given the average sprout counts (in percent) for all treatments in all soils.

Table 4.—Average of total sprout counts (percent) of each treatment for all soils.

Treatment	Rate	Percent total sprouts
Arasan	1:100	107.5
New Improved Ceresan	6 oz:100	105.3
Phygon	1:200	105.4
Check		79.7
Significant difference (odds 19:1)		9.7

As an average for all soils the three treatments were significantly better than the check, but there were no significant differences between Arasan, New Improved Ceresan, and Phygon in any one soil.

The average sprouts obtained from each of the 3 treatments (excluding check) was figured on the basis of 100 seeds planted and is given in table 5.

Table 5.—Average sprout count of treated seed (on basis of 100 seeds) obtained in nine different soils.

Soil source	Sprouts per 100 seeds
Oxnard	107.9
Clarksburg	106.9
American Island	100.0
Missoula	110.4
Rocky Ford	110.5
Lubbock	126.3
Grand Island	93.4
Chaska	88.4
East Grand Forks	111.7
Sig. diff. (19:1)	17.0

The counts in table 5 indicate that the seed treatments did not give the same degree of protection in all the soils. This is to be expected since the organisms causing damping off are probably different in some of the soils.

Conclusions

The seed treatments used in the Rocky Ford and Lamar tests did not give significant increases in stand except in the case of Phygon at Rocky Ford, and this in only one test. There was a tendency for the seed treatments used to depress the stands.

Significantly better stands were obtained from New Improved Ceresan in the test at Center, Colo.

Arasan gave significantly better stands than no treatment at East Grand Forks, Minn., and at Grand Island, Neb. New Improved Ceresan was significantly better than Yellow Cuprocide but was not significantly better than Arasan at East Grand Forks.

Seed treatment tests conducted in the greenhouse in nine different soils gave significantly better stands when sheared seed was treated with Arasan, New Improved Ceresan, and Phygon than did untreated seed. There were no significant differences among the three treatments for any one soil, nor was any one of the treatments significantly better in one soil and significantly poorer in another soil.

The degree of protection afforded by the three seed treatments was not the same for all soils; for example, significantly better stands were obtained in the soil from Lubbock, Texas, than in the soil from Chaska, Minn. This is most likely a function of the organisms caus ing damping off in the different soils.

Black Root of Sugar Beets and Possibilities for Its Control

G. H. Coons, J. E. Kotila, and H. W. Bockstahler[1]

In the humid area seedling diseases, commonly called black root, are the major factor responsible for poor stands of sugar beets. These diseases occur in this area in far more aggravated form than in most sugar beet districts of western United States, presumably because soil moisture conditions are not subject to the control that is possible if the crop is grown under irrigation. In irrigated districts there is reasonable assurance that if the seed is properly planted in a suitably prepared and watered seedbed, the sugar beet plants will emerge and be regularly distributed in the row. In the humid area there is no such assurance. Emergence may be extremely irregular or the majority of the plants that do appear may die because of seedling diseases. Extremely gappy stands are the rule rather than the exception. Careful hand thinning may in part repair such a situation, but it is obvious that mechanical thinning may not safely be applied to fields in which the drill rows show extensive plant skips. If sheared seed is planted sparsely in order that the stand of seedlings may be mechanically blocked without hand thinning, loss of individual plants by seedling diseases may be so serious as to preclude this mechanized operation.

It is commonly recognized that introduction of mechanization in the growing of sugar beets is essential if, in the post-war period, the domestic industry is to survive the impact of world competition. Therefore the problem of adequate initial stands of sugar beets for the humid area is of paramount significance. Unless progress is made towards obtaining improved initial stands the industry in this area may not be able to advance comparably with other areas in its mechanization program.

The diseases responsible for poor stands in the humid area do more than cause abandonment of acreage, replanting, or attempts to grow a crop with inadequate plant populations. Their effects are not limited merely to killing of seedlings and making it difficult to obtain enough plants to constitute a profitable beet field in which mechanized operations can be employed. Many of the relict plants constituting the post-thinning stand continue to suffer from a diseased condition of the roots, traceable to infections contracted in the seed-

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ling stages. The black root problem thus expands into a general root rot problem whose control must begin with attainment of an initial stand of healthy plants that can be carried to harvest without serious disease loss. It is, therefore, not too much to say that development of adequate control measures for the black root complex as a whole is essential if the sugar beet industry in the humid area is to be maintained.

Pathogens Causing Black Root

Sugar beet growers designate the entire complex of seedling diseases that decimate their stands of sugar beets as black root, a descriptive name based upon the appearance of the dead or dying plants. Many fungi have been found capable of causing death of seedlings *(2, 3, 4, 5, 10, 11, 12, 19, 20, 24)*[2]. Among these, *Ppthium* spp., *Phoma betae* (Oud.) Frank, *Rhizoctonia solani* Kuehn (*Pellicularia filamentosa* (Pat.) Rogers, and *Aphanomyces chochlioides* Drechs. appear most important.

Because of the relation to control, a differentiation of black root into its acute and its chronic phases is made. If the sugar beet plant is attacked and killed during germination or in a week or two after emergence from the soil, the designation of such attack as acute is, of course, appropriate. All the organisims listed are capable of producing such effects under certain climatic and soil conditions. Attention has been called to the possibility that disease of plants in later stages of growth may trace back to infections contracted in the seedling stage (*8, 10*). Buchholtz and Meredith have described the sequence of infection of *P. debaryanum* Hesse and *A. cochlioides (4)*. For *Phoma betae* a type of commensalism between the fungus and sugar beet has been reported by Edson *(13)*. However, under drought conditions or during storage, rotting of the roots by this fungus may occur (*17, 23*). *Rhizoctonia solani* commonly produces cankering of the hypocotyls and roots. A subsequent recrudescence of growth of the fungus in these cankers leads to crown rot (*6, 8*). Necrosis of the lateral roots or terminal portions of the tap root as caused by *A. cochlioides* has been described *(3, 9, 11, 16, 22)*. These various disease aspects are chronic phases of black root that may persist throughout the life of the sugar beet plant.

The chronic effects of *A. cochlioides* are particularly serious. Plants affected with this fungus show great lag in growth in comparison with healthy plants. This slow-down in growth is attributable to the continuing attack by the fungus upon the lateral rootlets *(16)*. When an affected plant is taken from the soil the absence of an adequate complement of feeding roots is apparent. In the early

[2]Italic numbers in parentheses refer to literature cited.

stages, leaf effects simulating a mosaic may appear. Affected plants remain dwarfed and many never reach marketable size. Under wet soil conditions terminal portions of the tap root may rot. Necrosis of the root tissue and lack of adequate root connections with the soil bring about wilting and death of the plants.

Both acute and chronic forms of the attack of *A. cochlioides* and of the other pathogens occur commonly in the beet fields of the humid area. The initial stand is reduced by acute attack, but, in spite of heavy loss of seedlings, careful thinning may retain a more or less adequate stand. But the plants that remain may continue to be subject to the chronic phases of black root.

Samples of diseased seedlings from any field may give isolations of any or all of the pathogens. Only extensive laboratory work in cultivating the fungi from the samples and consideration of the quantitative relations among the organisms obtained, together with deductions based on knowledge of the types of attack of the different pathogens, permit decision as to the particular organism (or organisms) doing primary or major damage in a given situation. Studies of this character in the humid area over the past 15 years have resolved the problem into its essential components leading to differentiation among the organisms as to their types of attack, their relative importance, and control measures applicable.

Among the organisms causing black root, only *Phoma betae* is known to be seed borne. Black root in subsequent crops has not been traced to earlier introductions of this fungus. The other species cited as important in the black root complex probably occur naturally in all agricultural soils and are present to a greater or lesser extent in any field likely to be planted to sugar beets. The degree of soil infestation, therefore, is a factor influencing prevalence of black root. Along with the degree of soil infestation, climatic and soil conditions, including the fertility level of the soil, are factors determinative of the extent to which black root may affect the crop. The interplay of these factors in relation to incidence of black root has been discussed elsewhere (*8, 9*) and is generally recognized by specialists on sugar beet diseases (*1, 11, 12, 21, 24*).

Possibilities for Black Root Control

Direct Measures

Treatment of sugar beet seed with a fungicide constitutes a practical means for reducing injury from black root (*10, 14, 18, 20*). The importance of treatment for sheared, or segmented, seed has been pointed out by Leach (*18*). Protective effects against the seed-borne fungus, *Phoma betae,* are comparable to those obtained in treating

of grain with fungicides. The protective effects against soil-borne organisms depend upon the disinfectant or warding-off action of the fungicide in the zone of soil surrounding the seed (*10*).

Many fungicides have been shown to have value for sugar beet seed treatment—copper compounds, mercury compounds, and, more recently, non-metallic fungicides such as, carbonates and quinolic derivatives. The results from a series of replicated tests in the period 1938-1942 (table 1) are typical of those obtainable from seed treatment experiments. The data are expressed in terms of Ceresan (2-percent ethyl mercury chloride) treatment. It will be noted that in any year in which seedling diseases were a factor, nearly all the fungicides used for seed treatment gave significantly better stands than were obtained from untreated seed. In cases in which disease impact was minor, the treatments at least did not depress the stands. No treatment tested over several years in this series was outstandingly superior to Ceresan, but several did not differ significantly.

It is characteristic of results from treatment of seed with an effective fungicide that very often a reasonably good stand of sugar beets is maintained until thinning time. The seed treatments do not, however, assure plant health over a long period. Post-thinning stands have sometimes deteriorated badly (*1, 5, 10*). Frequently no significant differences could be shown at harvest time between treated and untreated plots. Such results have tended to obscure whatever of benefit may have accrued from the treatment. Apparently the chief value of seed treatment is the prevention or reduction of the acute phases of black root. But this protection, even if limited, warrants general adoption of the treatment of sugar beet seed with some appropriate fungicide and is especially required for sheared seed planted at the customary low planting rates.

Indirect Measures

Crop Sequence in Relation to Black Root.—Certain crops grown preceding the sugar beet crop may have decisive effect on the prevalence in the soil of the pathogens causing black root. Legumes such as alfalfa, sweetclover, and the clovers have been found to harbor the organisms that attack the sugar beet. The roots and residues from these legumes favor the growth in the soil of these organisms. Weeds, such as red root pigweed and other species of *Amaranthus* also favor the increase of the black root organisms. On the other hand, crops such as corn, soybeans, and to some extent small grains exercise a sanitative effect, repressing the sugar beet pathogens, probably because residues from these crops support a different fungus flora in the soil. This relationship of the crops preceding the sugar beet to inci-

Table 1.—Sugar beet seedling stands* in seed treatment experiments, 1938 to 1942. Data of the individual, replicated tests in Michigan, Ohio, and Virginia in 1938, and in Michigan 1939-1942, inclusive, are given as percentages of counts obtained from Ceresan-treated seed.

Chemical dust treatment	Dosage of chemical to seed	1938 Mich.	1938 Ohio	1938 Va.	1939 Mich.	1940 Mich.	1941 Mich.	1942 Mich.	Average
		Percentage	Percentage	Percentage	Percentage	Percentage	Percentage	Percentage	Percentage
Ceresan (2-percent ethyl mercury chloride)	1:80	100	100	100	100	100	100	100	100
Ceresan, copper carbonate, 2:1	1:80	85	106	89	112	94	91	100	96.7
New Improved Ceresan, (5-percent ethyl mercury phosphate)	1:300	82	102	93	92	108	88	99	94.8
New Improved Ceresan, copper carbonate 1:1	1:300	.....	.....	.....	106	94	91	88	94.7
Copper carbonate	1:60	77	92	118	102	82	78	.....	91.5
Cuprocide	1:50	102	93	97	102	.....	92	112	99.7
Mercuric iodide, talc 1:14	1:100	84	105	73	.....	.....	.....	.....	87.3
Mercuric iodide, copper carbonate 1:14	1:100	94	100	79	69	100	86	99	89.6
Mercuric iodide, ($CuCO_3$ + Celite 1:1)1:14	1:100	.....	.....	.....	.....	114	100	100	104.7
Mercury bichloride, copper carbonate, urea 1:1:1	1:60	74	93	91	62	86	84	.....	81.3
Mercury bichloride, copper carbonate, urea 1:7:4	1:60	50	77	67	.....	.....	.....	.....	64.7
Arasan (Du Bay 1205)	1:100	.....	.....	.....	.....	.....	.....	117	117.0
Spergon	1:33	.....	.....	.....	.....	.....	.....	62	62.0
Check		30	98	78	68	71	22	78	63.6
Difference required for significance, odds 19:1		15.6	11.7	13.5	7.3	14.7	16.3	9.4	

*Stand records were obtained in the various years either by counting all seedlings in a given row-length or by determining the inches of row containing seedlings in some fixed row-lengths.

dence of black root was first pointed out in 1924 (*6*) on the basis of field observations near Caro, Mich. Confirmatory experimental evidence was reported in 1935 (*7*).

A rearrangement of fields on the farm, or the throwing together of two fields to form one field, affords the opportunity to see sugar beet plantings that are otherwise comparable except for the difference in the cropping history of sections or strips of the field. Two fields in which legume-sugar beet and corn-sugar beet sequences occurred under otherwise comparable conditions are shown in figures 1 and 2.

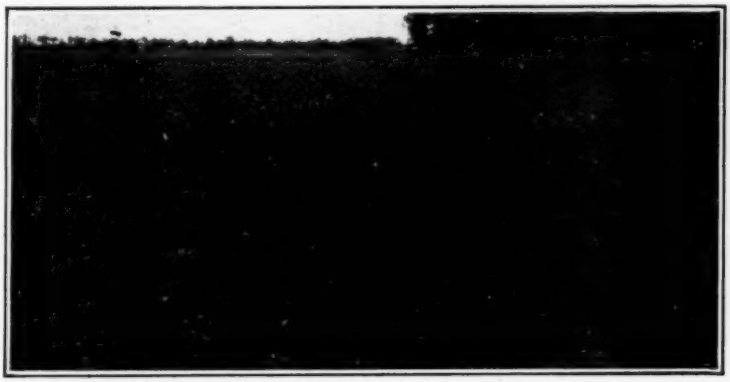

Figure 1.—Effect of crop sequence on sugar beet black root. The sugar beets in the foreground followed a previous crop of sweetclover; those in the background followed corn. Two fields were thrown together prior to preparation for the beet crop. The break between poor stands and poor growth of sugar beets and good stand and good growth came at the old fence line. A. W. Smith farm, Malinta, Ohio.

In the portions of the photographs in which the stands are adequate, the sugar beets are grown following corn; the sections with poor stands mark to the row the portions of the field in which legumes immediately preceded the sugar beets.

Results from a replicated crop-sequence experiment conducted in 1942 and 1943 at Beltsville, Md., illustrate the effects on stands attributable to crop sequence. In this experiment a split-plot design was used to contrast manuring vs. no manuring in connection with the different crop sequences, but no significant interaction of crops x manuring was found. The entire experimental area was spring plowed. It will be noted that the land that was held fallow (clean culture in 1942) gave, for the conditions of the test, a fair stand of sugar beets. The stands when sugar beets followed corn and soybeans were significantly better than on the fallowed plots, whereas sweetclover, and a mixture of corn and sweetclover, as preceding crops showed significantly depressed stands (table 2).

Figure 2.—Effect of crop sequence on sugar beet black root. The sugar beets at the left were grown following corn. The nine rows at the right fell on land that was in sweetclover the previous year. Blocking operations on these nine rows were delayed 2 weeks because of retarded growth of the sugar beet plants. H. S. Gray farm. Malinta, Ohio.

In a small three-times-replicated test conducted in the same field, similar trends were shown, but significant differences were not obtained between corn as a preceding crop and sweetclover or red clover as preceding crops. The outstanding result in this experiment was the depressed stand when *Amaranthus retroflexus* was allowed to grow as a dense stand in 1942 and was followed by sugar beets in 1943 (table 3).

Table 2.—Stands (22 inches x 22 inches) obtained with sugar beets grown following various preparatory crops or on fallowed plots. Random block arrangement, five replications. Plot area 15 feet x 110 feet, of which center four rows were counted. In each crop sequence half-plots (55 feet long) received manure (10 tons per acre). Plots plowed for sugar beets on March 29, 1943. (Results given as five-plot averages.)

Preparatory crop or treatment	Stand after mechanical blocking 22 inches by 22 inches		
	Manured	No manure	Total
Sweetclover	36.0	32.4	68.4
Corn	68.2	58.0	126.2
Mixed stand of corn and sweetclover	40.8	25.0	75.8
Soybeans	69.6	60.6	130.2
Fallow	50.2	52.4	102.6
Difference required for significance, odds 19:1			17.76

Table 3.—Stands of sugar beets obtained in crop sequence test involving a number of crops grown in 1942 and followed by sugar beets in 1943. Plots 15 feet x 33 feet. Three replications. Beltsville, Md., 1942-1943.

Preceding crop or treatment	Seedlings*				Stand (22 inches x 22 inches) in four rows			
	1	2	3	Aver.	1	2	3	Aver.
Corn	154	143	162	153.0	41	42	57	46.7
Sweetclover	82	70	200	117.3	41	43	36	40.0
Red clover	111	109	111	110.3	31	43	49	41.0
Ladino clover	144	123	127	131.3	40	31	45	38.7
Amaranthus retroflexus	81	35	110	75.7	9	5	29	14.3
Fallowed	75	121	91	95.7	36	42	26	34.7
Sweet corn	79	98	148	108.3	33	43	50	42.0
Soybeans	142	138	169	149.7	51	48	48	49.0
Cowpeas	122	109	141	124.0	46	40	58	48.0
White pea bean	116	73	129	106.0	38	18	49	35.0
Difference required for significance, odds 19:1				43.4				13.5

*In rows 5 and 7 of each plot, beet-containing inches for a total of 400 inches were determined.

The effects on subsequent sugar beet crops of the sod-forming legumes as contrasted with those from corn or soybeans occur irrespective of soil types. They have been duplicated under controlled conditions in the greenhouse with a substratum of autoclaved quartz sand supplied with Eaton's mineral nutrient solution. As the experiment was set up there were three series of preparatory treatments—one in which corn seedlings were grown, one in which sweetclover seedlings were grown, and the control consisting of the substratum without crop plants. Each series comprised 28 crocks. Seven inoculation treatments, four times replicated, were used. These treatments consisted, for each series, of (1) control, (2) inoculation with a pure culture of *Rhizoctonia solani*, (3) inoculation with a pure culture of *Aphanomyces cochlioides*, (4) inoculation with non-pathogenic organisms (*Rhizopus* spp., *Penicillium* spp., and others), (5) addition to the crocks of macerated, damped-off sugar beet seedlings (chiefly by *A. cochlioides*), (6) inoculation with a pure culture of *R. solani* mixed with non-pathogens, and (7) inoculation with a pure culture of *A. cochlioides* mixed with the non-pathogens. In all, 84 crocks were used in the experiment and these were kept on rotating tables in the greenhouse in order to equalize environmental conditions. The corn and sweetclover crops were grown for 36 days; then the tops were cut and removed. Thirty-seven days later 50 sugar beet seed balls were planted in each crock. The results after 3 weeks are shown in table 4.

In the control series with only quartz sand and mineral nutrients present, the pathogenic organisms that were introduced did not in-

Table 4.—Influence of corn and sweetclover on damping-off of sugar beets by various organisms. Quartz sand plus nutrient substratum was inoculated with organisms; then corn or sweetclover was grown for 36 days and then tops removed. One series was maintained without green plant growth. Sugar beet seed was planted 37 days after top removal, 50 seed balls per 3-gallon culture jar: Data are given as seedling counts per culture jar after 3 weeks. Arlington, Va. (Data given as four-culture averages.)

No.	Inoculation treatments	Average number of sugar beet seedlings after the preparatory treatments		
		Fallow	Corn grown 36 days	Sweetclover grown 36 days
1	None	67.2	48.7	64.1
2	Rhizoctonia solani (Pure culture)	71.2	48.7	30.5
3	Aphanomyces cochlioides (Pure culture)	73.7	59.2	10.0
4	Non-pathogenic organisms (Mixed cultures)	64.5	60.2	55.2
5	Damped-off sugar beet seedlings (macerated)	48.0	46.0	2.0
6	R. solani (Pure culture) plus non-pathogenes of No. 4	76.0	64.2	24.2
7.	A. cochlioides (Pure culture) plus non-pathogenes of No. 4	72.0	48.0	34.2
	Average	67.5	53.6	31.5

Differences required for significance
Between inoculation treatments 19.4
Between preparatory treatments 12.8

crease to any considerable extent, judging by the nearly normal stands obtained. In the series in which corn was grown as a preparatory treatment, the corn roots did not greatly increase the pathogenic content of the quartz sand substratum judging by the stands of seedlings obtained. On the other hand, the growing of sweetclover did very decidedly increase the damping-off of sugar beets by the organisms initially added. *A. cochlioides* and the undetermined organisms from the damped-off seedlings reduced the stands by the greatest extent, but *Rhizoctonia* also was significantly effective. It was expected that the non-pathogenic organisms might repress the pathogens, but under the conditions of this test they had limited but probably positive effects on *A. cochlioides*.

Plowing Legume Sods at the Proper Time.—The deleterious effects assignable to increase in the degree that the soil is infested with the black root organisms because of the growth and the residues from the sod legumes or from such weeds as *Amaranthus retroflexus* growing in thick stands seem to be associated with the usual timing of plowing in preparation for the beet crop.

Reports of successful sugar beet crops following alfalfa indicated upon close study that the period when the legume sod was plowed may be an important factor. Replicated experiments in Colorado,

South Dakota, Ohio, and at Beltsville, Md., gave evidence on the definite relationship between the plowing date of the alfalfa sod and the amount of black root injury in the subsequent sugar beet crop. Independently conducted experiments by Morris and Afanasiev (*21*) in Montana have also given very striking evidence of this relationship.

Table 5.—Stands (22 inches x 22 inches) of sugar beets on sweetclover sods, as influenced by dates of plowing. Main plot area 15 feet x 110 feet, of which the center four rows were counted. For each plowing date, half-plots received manure (10 tons per acre). Beltsville, Md., 1942, 1943 (Results given as five-plot averages.)

Date of plowing sweetclover sod	Stand of sugar beets		
	Manured	No manure	Total
August 26, 1942	39.2	50.4	89.6
September 15, 1942	67.8	66.4	134.0
November 16, 1942	44.8	38.6	83.4
February 23, 1943	40.0	34.0	74.0
March 29, 1943	36.0	32.4	68.4
April 15, 1943	41.2	28.0	69.2
Difference required for significance			18.89

Interaction of Manure Treatment x Time of Plowing was not significant.

The results from the 1942-1943 Beltsville test are cited (table 5). In this replicated test, a split-plot design was used to superimpose the manure vs. no manure factor upon the main factor, time of plowing a sweetclover sod. The interaction of manuring and time of plowing was not significant in this test. The mean stand of the plots plowed February 23, March 29, and April 5, 1943, was significantly below the mean of the plots plowed in 1942. The relatively poor showing of the plots plowed August 26, 1942, is not understood, unless it is associated with uncontrolled weed growth that occurred after the plowing. The intermediate position with respect to stand as found for the November plowing was not unexpected.

A plausible explanation of the relation between time of plowing the legume sods and degree of soil infestation can be drawn from soil microbiology studies. It is well known that, subject to soil temperature and moisture conditions, the addition to the soil of a crop residue or other nutrient favorable for the growth of a particular class of organisms is immediately followed by an enormous increase in these organisms. From a relatively minor group they may become the dominant forms. When these organisms have exhausted their food supply, then other organisms follow in the cycle, disintegrating what is left and crowding out the former dominant forms. If a legume sod, or other residue, that steps up the prevalence of the sugar beet pathogens be plowed very late in the fall or in early spring, then the

peak of development of the organisms pathogenic to sugar beets is very likely to coincide with the planting dates for sugar beets. On the other hand, if alfalfa or sweetclover sods are turned under in August, September, or possibly even later, and if soil conditions permit disintegration of the residues, then the peak of the pathogen development may come and go and thus be entirely out of step with sugar beet planting dates. Under such a system of handling legume sods, the adverse effects on sugar beet stands may not occur.

Blanket recommendation to plant sugar beets on legume sods without specification as to time of turning under these sods is ill-advised. In the humid area, legume sods are so commonly plowed under in late fall or early spring that such an unqualified recommendation invites a black root outbreak. But the deleterious effects from legume sods can be avoided, and the benefits from the legume-sugar beet sequence obtained, if proper timing in plowing under the legume sod is observed. The sods must be turned under early enough in the preceding year so that decomposition of the legume residues may be completed and the fungi pathogenic to sugar beets be replaced by nonpathogenic forms. Under normal conditions in the humid area, this means late August or September plowings to prepare an alfalfa, sweetclover, or clover field for sugar beets.

Application of Phosphate Fertilizer.—Field observations have indicated rather definite relationship between level of soil fertility and incidence of black root (*8*). Results from a replicated tested in 1932 at Malinta, Ohio, on Brookston clay soil so heavily infested with black root producing organisms that untreated plots failed completely, gave striking evidence of the efficacy of phosphate applications in black root control (figure 3). These leads were subsequently followed in field tests at various locations with similar demonstration of effectiveness of phosphate applications if these were adequate in amount. Results from a representative test conducted in 1942 in cooperation with the Ohio Agricultural Experiment Station at Holgate, Ohio, are summarized in table 6. Young (*24*) has reported results of tests at Elmore and at Holgate, Ohio, of the same import.

Experimental evidence on the decisive influence of phosphate nutrition in bringing about recovery of sugar beet plants from attack by *Aphanomyces cochlioides* was obtained in a replicated greenhouse test in which sugar beet plants, inoculated with a pure culture of *A. cochlioides* or with debris from diseased plants (chiefly *A. cochlioides* infection), were grown on a nutrient solution added to quartz sand. The details of the test have been reported (*16*). The diagrammatic summary omitted from the earlier report is shown as figure 4. In this test, an attempt was made to superimpose water level effects in the

Figure 3.—Effect of phosphate fertilizer on black root. Rows 65 and 66, shown at the center, received, respectively, a complete fertilizer high in phosphate and superphosphate, both at the rate of 500 pounds per acre. These treatments were outstanding in this replicated test. Seed treatment without fertilizer, and potash and nitrogen as single element treatments were not effective. Malinta, Ohio, 1932.

cultures, but results attributable to this factor were not pronounced and can be disregarded. The diagram shows the pronounced effect of phosphate in bringing about recovery of plants infected with *A. cochlioides*.

The increase of the *Aphanomyces* form of black root in many districts is very probably related to the progressive lowering of available phosphate that has taken place in many soils of the humid area. Deficiency of phosphate appears to lower the resistance of the sugar beet plants to *A. cochlioides*, but that the action is of this type has not as yet been positively demonstrated. Evidence has been given by Larmer (*17*) that a low status of phosphate nutrition reduces the resistance in storage of sugar beet roots to rotting caused by *Phoma betae*.

Abundant evidence is at hand, therefore, that raising the fertility level of the soil, particularly with respect to phosphate, can bring about very decisive reduction of the losses caused by *A. cochlioides*. Although the fertilizer practice with sugar beets has shown marked improvement in recent years, there is still need to break down the tendency to use the phosphate fertilizers so sparingly that little or no benefit is obtained.

Breeding for Black Root Resistance

So long as control of black root by breeding involved taking into account the entire group of pathogens capable of attacking in the

Table 6.—Results from soil treatment experiment, Holgate, Ohio, in 1942 (cooperative with Ohio Agricultural Experiment Station). 12 x 8 randomized block design; plots consisted of four rows (21 inches) 48 feet long. Center rows harvested.

	Acre yield		Sucrose	Purity	Inches of row containing seedlings	Stand after thinning	Harvested stand
	I. A. sugar	Roots					
	Pounds	Tons	Percent	Percent	Percent	Percent	Percent
No-Phosphate Series:							
Check, seed treated Ceresan	1,404*	6.78*	12.79*	80.59*	11.8*	34.7*	29.7*
Check, seed not treated	1,504*	7.26*	12.83*	80.85*	14.3	41.7*	33.6*
$(NH_4)_2SO_4$, 80 pounds N per acre, seed not treated	1,315*	6.52*	12.62*	80.19*	6.5*	24.1*	21.7*
K_2SO_4, 82½ pounds per acre, seed not treated	1,774*	8.25*	13.13	81.89	16.3	45.1	37.8*
Phosphate Series:							
0-45-0, 180 pounds per acre, seed not treated	2,496	11.06	13.58	82.85	16.5	50.4	47.8
0-45-0, 180 pounds per acre, seed treated	2,255	10.15	13.43	82.72	15.4	52.0	44.9
0-20-0, 200 pounds per acre, seed not treated	2,618*	11.37*	13.77	83.74*	13.3	54.3*	49.8*
0-20-0, 400 pounds per acre, seed not treated	2,846*	11.91*	14.14*	84.67*	25.0*	64.0*	58.6*
0-20-0 + 3% Zno, 400 pounds per acre, seed not treated	2,996*	12.99*	13.72	84.07*	28.1*	69.2*	61.0*
0-20-0 + 6% ($CuSO_4$ and CaO, 1:1) 400 pounds per acre, seed not treated	2,901*	12.41*	13.90*	84.03*	24.8*	67.0*	60.4*
Ammophos:							
11-48 Ammophos, 167 pounds per acre, seed not treated	1,003*	4.99*	12.54*	80.10*	5.0*	15.6*	15.0*
Complete Fertilizer:							
2-16-8, 500 punds per acre, seed not treated	3,289*	13.98*	13.97*	84.25*	23.2*	65.9*	61.6*
Difference required for significance, odds 19:1	310	1.35	.48	1.2	4.3	5.9	6.5
General mean	2,200	9.8	13.37	82.5	16.7	48.9	43.5

*A value marked with an asterisk differs significantly from the general mean.

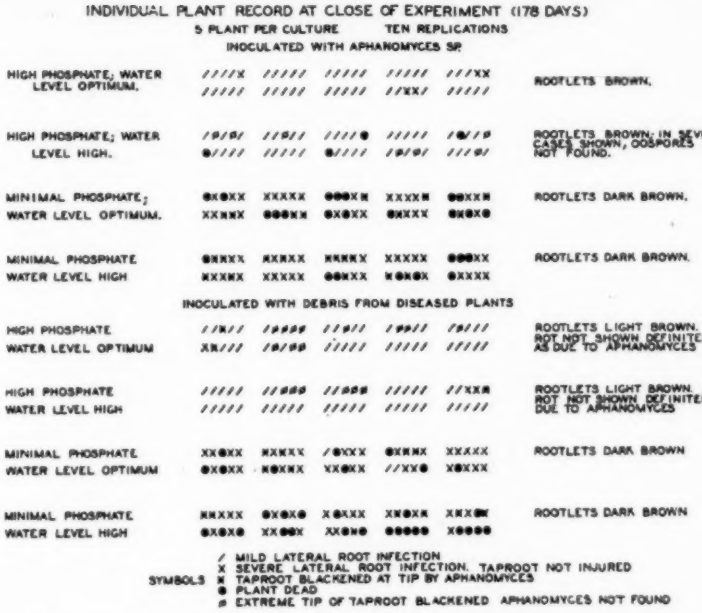
INDIVIDUAL PLANT RECORD AT CLOSE OF EXPERIMENT (178 DAYS)
5 PLANT PER CULTURE TEN REPLICATIONS
INOCULATED WITH APHANOMYCES SP.
HIGH PHOSPHATE; WATER LEVEL OPTIMUM.
ROOTLETS BROWN.
HIGH PHOSPHATE; WATER LEVEL HIGH.
ROOTLETS BROWN; IN SEVERE CASES SHOWN, OOSPORES NOT FOUND.
MINIMAL PHOSPHATE; WATER LEVEL OPTIMUM.
ROOTLETS DARK BROWN.
MINIMAL PHOSPHATE WATER LEVEL HIGH
ROOTLETS DARK BROWN.
INOCULATED WITH DEBRIS FROM DISEASED PLANTS
HIGH PHOSPHATE WATER LEVEL OPTIMUM
ROOTLETS LIGHT BROWN. TIP ROT NOT SHOWN DEFINITELY AS DUE TO APHANOMYCES
HIGH PHOSPHATE WATER LEVEL HIGH
ROOTLETS LIGHT BROWN. TIP ROT NOT SHOWN DEFINITELY DUE TO APHANOMYCES
MINIMAL PHOSPHATE WATER LEVEL OPTIMUM
ROOTLETS DARK BROWN
MINIMAL PHOSPHATE WATER LEVEL HIGH
ROOTLETS DARK BROWN
SYMBOLS
/ MILD LATERAL ROOT INFECTION
X SEVERE LATERAL ROOT INFECTION. TAPROOT NOT INJURED
⊗ TAPROOT BLACKENED AT TIP BY APHANOMYCES
● PLANT DEAD
ø EXTREME TIP OF TAPROOT BLACKENED APHANOMYCES NOT FOUND

Figure 4.—Effect of phosphate nutrition in producing recovery of sugar beet plants from Aphanomyces cochlioides infection. The sugar beets were grown in 3-gallon crocks to which a nutrient solution high in phosphate was added to half the cultures, the other half receiving nutrient with a minimal amount of phosphate. Different water levels were superimposed on the nutrition factor, but effects from this factor were not pronounced. Inoculum was of two types: a pure culture of A. cochlioides and debris from plants known to be infected with this organism.

seedling period and persisting in the later stages of growth, the outlook for obtaining blanket resistance to all pathogens seemed hopeless. Strains resistant to one fungus could not be expected to show similar resistance to other non-related organisms. With the resolution of the complex into its factors, and in view of the success of seed treatments in preventing the acute stages, it is now possible to center attention in breeding investigations on the chronic phases of *A. cochlioides*.

Observations made on the agronomic evaluation tests of U. S. leaf spot resistant varieties in 1940 and 1941 in Michigan, Ohio, Wisconsin, and Minesota, and confirmed by the records taken in 1940 by J. H. Torrie in connection with the evaluation tests in Wisconsin and the observations by A. R. Downie and J. O. Culbertson in Minnesota, indicated that U. S. 216, a leaf spot resistant inbred line, had definite resistance to the chronic phase of *A. cochlioides* attack. Furthermore, hybrids of U. S. 216 with other inbreds in which resistance had not

been noted also were found to be comparable in resistance to U. S. 216. The resistance of U. S. 216 was manifested by its relatively better seedling stand in comparison with that from European sugar beet varieties or from U. S. 200 x 215, and the relative freedom from rotting of the terminal portion of the tap root, a condition that was pronounced in some other inbred lines and in mass selected material.

In 1941 many of the U. S. varieties in the leaf-spot-resistance evaluation tests had U. S. 216 as a component variety. These were resistant to chronic phases of *A. cochlioides*. One variety, SP 1-9-00, was produced by allowing the inbred lines U. S. 215 and 8-266-0 to intercross. No resistance had been noted for these two inbreds. In the comparative tests in Michigan, Ohio, and Minnesota, SP 1-9-00 was so conspicuously dwarfed by *A. cochlioides* that the variety could be identified by the depressed growth alone. Whereas this variety showed excellent tonnage in the tests under irrigation, in nearly all tests in the humid area its susceptibility to *A. cochlioides* was so great that it fell significantly below the other varieties in root yield and sugar production. The susceptibility and poor performance were in marked contrast to the resistance and excellent performance of another hybrid, SP 0-281-00, produced by crossing U. S. 216 with the inbred 8-266-0.

In 1943 and 1944, plantings were made on heavily infested soil to obtain further information and to make selections. No phosphate fertilizers were used and the seed was untreated. Extremely wet weather brought about such loss of seedling stand by the acute phases of black root, including *Pythium* spp., that these tests yielded little except evidence that the seedlings must be protected by seed treatment from impact of the other damping-off organisms if any plants are to be available in the field for selection against the chronic phase of *A. cochlioides*. The progress made in 1945 investigations is reported by Henderson and Bockstahler (*15*).

The degree of resistance found in U. S. 216 and its hybrids is limited. Under severe exposures the yields may be as low as 5 tons per acre, but under these conditions susceptible varieties may almost fail. The factors for resistance therefore make definite contribution. The situation may not be unlike that which was faced when U. S. 1, the first curly top resistant variety, was introduced. It was necessary to plant U. S. 1 early, make adequate fertilizer applications, and provide proper cultural conditions in order to utilize to the full its rather limited curly top resistance. Continued selections have now resulted in sugar beet varieties very greatly improved in curly top resistance.

Varieties with the degree of resistance now found may be expected to show advantage in withstanding the chronic type of attack

and to grow in spite of *A. cochlioides*. Utilization with them of the helpful direct and indirect measures for black root control is essential and should result in alleviation of the disease losses sustained with non-resistant sorts. The discovery that factors for resistance exist in strains of sugar beet that are also leaf spot resistant makes the outlook for ultimate control of both diseases promising.

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Seed-Borne Phoma and Its Relation to the Origin of Sugar Beet Seed Lots

L. D. LEACH[1]

Among seedling diseases of sugar beets the form caused by *Phoma Betae* (Oud.) Frank is unique in that the casual organism is seed-borne, whereas other types of seedling diseases are caused by soil-inhabiting fungi.

In Central California damping-off caused by *Pythium ultimum* Trow is considered to be the most widespread and destructive seedling disease. The beet water mold seedling disease caused by *Aphanomyces cochlioides* Drechsler, however, is often more destructive in the mid-season or late-planted fields in peat or semi-peat soils of the Delta region. *Rhizoctonia solani* Kuhn causes a large part of the infection in some fields, especially following beans or potatoes. Late-planted fields with abundant moisture occasionally suffer severe infection from *Pythium aphanidermatum* (Eds.) Fitzp. All the four species mentioned in this paragraph are soil-borne organisms.

Phoma infection of seedling beets in severe form has been observed by the writer only in connection with a few lots of seed, and therefore an attempt was made to determine the factors associated with these severe infections.

European sugar beet seed is known to carry *Phoma betae* on many seed lots. In 1934 Schmidt (*9*)[2] reported that this fungus was regularly present on ordinary commercial seed to the extent of 40 to 100 percent, its prevalence being directly proportionate to the humidity of the climate in the area of seed production. Edson (*2*) found *Phoma* to be present on all the imported seed lots he examined.

Infection on domestic seed was also reported by Edson (*2*) and by Pool and McKay (*6*), who observed heavy infection of seed crops growing in Idaho and Colorado in 1912 and 1913 and of beet seed balls produced in these fields. Coons (*1*) reported *Phoma* infection on seed grown in isolation plots in Michigan.

Early increases of domestic seed in southwestern United States, however, appeared to be free from infection. In 1940 the writer (*3*) reported that among 19 lots of domestic seed grown in Southern California and Arizona which were examined by microscopic observation of incubated seeds, none showed *Phoma* infection. At the same

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[2]Italic numbers in parentheses refer to literature cited.

time 52 lots of European seed were examined in a similar manner. More than half the lots showed some *Phoma* infection and eight showed more than 10 percent of the seed balls infected.

During the following year, however, *Phoma* infected seedlings were found in greenhouse plantings of domestic seed in sterile soil. In 1942 specimens of sugar beet seed stalks infected by *Phoma* blight and bearing infected flowers and seed balls were received from Oregon and Northern California. Similar specimens were identified by Dr. F. P. McWhorter of the Oregon Agricultural Experiment Station.

Determination of Seed Infection

To test the incidence of *Phoma* infection on seed used for planting in California, a large number of samples were obtained from the sugar companies and from seed-producing companies. A limited number of samples were also furnished by companies operating in other areas. Seed from each lot was planted in pasteurized soil in the greenhouse and seedlings were examined for damping-off or root infection. Isolations from infected seedlings served to identify the causal organism.

Among 125 seed lots examined, 24 lots were found heavily infected, while the remainder showed light to moderate infection or appeared to be disease free (*4*). Results with 91 lots identified as to origin are shown in table 1.

Severity of infection was apparently related to the summer rainfall or moisture in the seed-producing areas, being heavy on several seed lots from the Willamette Valley of Oregon where overhead

Table 1.—Relation of origin of seed to Phoma infection on seedlings in pasteurized soil

Seed produced	Precipitation June-Sept. (Inches)*	Temperature July mean F°*	No. of seed lots showing Phoma infection: Percent of seedlings infected				
			none	0.1-5%	5-20%	20-50%	over50%
California							
Hemet Valley	0.53	77.6	5	14	2	0	0
Shasta Valley	1.83	72.7	1	2	5	0	1
Oregon							
Medford	2.03	72.0	2	8	12	3	4
Klamath Falls	1.71	68.2	0	3	0	0	0
Willamette Valley	3.48	65.9	0	1	1	1	16
Utah							
St. George	2.69	82.9	1	0	3	2	1
Ogden	3.55	74.7	0	1	1	1	0

*Data from Climate and Man. U. S. Dept. Agr. Yearbook, 1941.

irrigation of sugar beet seed crops was practiced; light to moderate on seed from Medford, Ore.; Shasta Valley, Calif.; and St. George, Utah; and extremely light on seed from Hemet Valley, Calif. Heavily infected lots were also identified from Colorado and Michigan but not enough samples were tested from these or other areas to justify any generalizations.

The practice of harvesting two successive seed crops from the same roots often resulted in several times as much *Phoma* infection on the second, called the "carry-over" crop, as on the first crop. In fact all the heavily infected lots from the Medford, Ore., area were from "carry-over" crops.

Stock seeds used for plantings in Oregon and California from 1940 to 1942 appeared to be disease free or only lightly infected. The seed, therefore, can not be considered the primary source of inoculum for the heavily infected seed crops produced during that period. In 1943, however, four heavily infected lots of stock seed were planted in Hemet Valley. Observations by Dr. John T. Middleton showed no evidence of leaf spot or stalk blight on the seed crops produced in 1944 from these lots. Comparative tests of the stock seed and the commercial crops produced from them are shown in table 2. Blended

Table 2.—Comparison of seed-borne Phoma on stock seed planted and on seed produced in Hemet Valley, Calif., 1943-4.

Variety	Stock seed produced	Seed planted		Seed produced Hemet Valley, Calif.	
		Lot No.	Phoma inf. (Percent)	Lot No.	Phoma inf. (Percent)
U. S. 215 x 216	Willamette Valley, Oregon	2380	46.3	404	0.0
U. S. 215 x 216	Willamette Valley, Oregon	2391	70.2	416	0.8
Imperial 40	Willamette Valley, Oregon	2323	59.8	406	1.8
Imperial 40	Willamette Valley, Oregon	2337	67.1	444	0.0
U. S. 22	Avon, Utah	4202	2.1	323	0.3
U. S. 33	Gazelle, Calif.	4203	0.0	331	0.3

seed from lots 2380 and 2391, both heavily infected, were planted to produce lots 404 and 416 which showed practically no infection. In the same way a blend of lots 2323 and 2337, both heavily infected, produced lots 406 and 444 with little or no infection. In the previous year seed lot 4202 (U. S. 22) with 2 percent *Phoma* infected seedlings and lot 4203 (U. S. 33) with no apparent infection produced seed lots showing less than 1 percent infected seedlings. Such low percentages of infection may have resulted from contamination after harvest and do not necessarily indicate field infection. It is evident that the combination of seed treatment (New Improved Ceresan) and environmental conditions unfavorable for the fungus practically eliminated the possibility of transmission of *Phoma betae* on seed produced in the Hemet Valley.

Circumstantial evidence indicated that in areas favorable for infection much of the inoculum originated in adjacent seed fields maturing at the same time the next year's crop was being planted or from remnants of a previous crop on the same field. Survival of the fungus on fragments of seed stalks for more than a year after harvest was demonstrated in one field in the Shasta Valley.

During 1944 when most of the seed crops in the Willamette Valley were produced in new areas and without overhead irrigation, the amount of infection on the seed was much less than in the previous 3 years.

Some lots of seed were found to carry *Phoma* in a viable form 5½ years after harvest. Successive trials showed, however, that in most seed lots the amount of infection dropped sharply within 2 or 3 years.

Seed Disinfection and Seedling Protection

Several methods of eliminating *Phoma betae* from beet seed balls have been proposed. Edson (*2*) found that Peter's method of heating the seed in water at 60° C. for 10 minutes on 2 successive days was very effective but did not consider this method practical for field use. Miss Rumbold (*8*) described the disinfection of beet seed with formaldehyde vapor and steam. This method was used to a limited extent between 1919 and 1923. In 1944 McWhorter and Miller (*5*) advocated vapor heat as a practical means of disinfecting seeds.

To determine the disinfecting power of several of the newer chemicals, beet seed carrying heavy *Phoma* infection was soaked in solutions or suspensions of the chemicals listed in table 3 for either

Table 3.—Liquid disinfectants for control of seed-borne Phoma.

Material	Dilution	Time (Minutes)	Emergence per 100 s.b.*	Infection (Percent)
Nontreated	.....	..	121	81.4
New Improved Ceresan	1-1200	5	147	2.8
New Improved Ceresan	1-1200	20	147	1.8
New Improved Ceresan + 1% wetting agent	1-1200	5	162	2.0
+ 1% wetting agent	1-1200	20	151	0.4
Lignasan	1-1500	5	146	2.8
Lignasan	1-1500	20	161	0.4
Wettable Phygon	1-800	20	152	16.7
Wettable Phygon	1-200	60	142	21.1
HE-175	1-200	20	171	8.6
Nontreated	.....	..	103	83.1

*Seedlings per 100 seed balls.

5 or 20 minutes and were then dried and planted in pasteurized soil. The results in table 3 show that ethyl mercury phosphate obtained from New Improved Ceresan or from Lignasan was highly effective in

eliminating *Phoma* from beet seeds. Subsequent tests showed that a 20-minute dip in a 1-1500 solution of Lignasan, equivalent to 40 p.p.m. of ethyl mercury phosphate, completely eliminated *Phoma* infection from 28 of the 32 seed lots tested. This treatment also provided protection against soil-borne damping-off fungi. Wettable Phygon (dichloro-naphthaquinone) and He-175 (disodium ethylene bisdithiocarbamate) appeared to be less effective than the organic mercury compounds.

All wet treatments have the disadvantage of requiring drying of the seed and therefore have limited application unless special equipment is used. Several dust fungicides are effective against *Phoma betae* either because they destroy the fungus on or in the seed ball or because they retard growth of the fungus enough to prevent seedling infection.

Comparisons between several dust fungicides are shown in tables 4 and 5. Ceresan and New Improved Ceresan appeared to be the most effective, with Phygon and Arasan also giving a high degree of control in most cases. Spergon, Fermate, and Yellow Cuprocide provided only partial control.

Table 4.—Dust fungicides for control of seed-borne Phoma.

Material	Dosage (Percent)	Seed lot A		Seed lot B	
		Emergence*	Infected seedlings (Percent)	Emergence*	Infected seedlings (Percent)
Nontreated	.....	129	70.2	173	45.4
Spergon	1.00	154	61.5	.....	.....
Fermate	1.00	143	23.6	.....	.....
Arasan	1.00	169	10.1	.....	.....
Yellow Cuprocide	1.50	.....	.....	183	22.7
Ceresan	1.00	153	0.0	204	0.6
New Improved Ceresan	0.375	.....	.....	201	0.7
Significant difference 19:1 odds		25.0	.....	12.3	.....

*Seedlings per 100 seed balls.

Effect of Seed-Borne *Phoma* on Laboratory Germination

With lightly infected seed lots, *Phoma betae* does not reduce the emergence of seedlings in soil or the germination of seed in laboratory tests. Certain heavily infected seed lots, however, show severe pre-emergence damping-off, especially at low temperatures. Porter and Rice (7) found that in three beet seed samples from Sweden, *Phoma betae* prevented the germination of many untreated seeds in blotters and the emergence of many seedlings in both sand and soil.

Table 5.—Dust fungicides for control of seed-borne Phoma.

Material	Dosage (Percent)	Seed lot A		Seed lot C		Seed lot D	
		Emergence*	Infected seedlings (Percent)	Emergence*	Infected seedlings (Percent)	Emergence*	Infected seedlings (Percent)
Non-treated	none	115	82.9	185	50.1	162	19.0
Arasan	0.25	157	19.5	211	5.7	176	0.0
Arasan	0.50	164	4.7	221	3.9	183	1.4
Arasan	1.00	175	12.7	203	4.7	179	0.0
Ceresan	1.00	177	3.7	217	1.7	177	0.0
Phygon	1.00	.....	.....	198	2.6	182	1.4
Significant difference 19:1 odds		26.6	.....	22.6	.....	n.s.	.....

*Seedlings per 100 seed balls.

The results of our germination tests with a heavily infected seed lot on blotters, in sand, and in soil are shown in table 6 in comparison with the same seed disinfected by immersion in an ethyl mercury phosphate solution. The greatest depression of germination occurred in sand and in soil at low temperature.

Table 6.—Effect of seed disinfection upon germination of Phoma-infected seed on blotters, in sand, and in soil.

	Laboratory germination*				Soil germination	
	Blotter		Sand		50° F.	80° F.
	Percent	Seedl./100†	Percent	Seedl./100†	Seedl./100†	Seedl./100†
Non-treated	71.5	120	57.5	100	100	122
Treated	77.0	130	75.5	128	138	142

*All laboratory germination tests were conducted by the California Seed Laboratory.
†Seedlings per 100 seed balls.

A comparison of the laboratory germination on blotters and in sand of three infected seed lots, both treated and non-treated, is presented in table 7. The emergence of each lot in an irrigated field planting is also shown.

These results suggest that to obtain a true measure of the potential germination of some *Phoma* infected seed lots it may be necessary to disinfect the seed balls for either laboratory or soil germination tests.

Summary

Seed-borne infection of *Phoma betae* has been found to occur on a number of sugar beet seed lots, especially those produced in

Table 7.—Laboratory germination and field emergence of treated and non-treated Phoma-infected lots of sugar beet seed.

Seed lot	Treatment	Laboratory germination*				Field emergence
		Blotter		Sand		
		Percent	Seedl./100†	Percent	Seedl./100†	Seedl./100†
A	Non-treated	78.75	123	66.50	105	82
A	Treated	84.50	133	79.00	128	112
B	Non-treated	87.75	163	82.00	154	123
B	Treated	94.00	194	92.50	185	164
C	Non-treated	77.75	149	72.00	143	80
C	Treated	85.25	167	81.00	164	142

*All laboratory germination tests weer conducted by the California Seed Laboratory.
†Seedlings per 100 seed balls.

regions with showers or high humidity during the period of seed maturity and harvest.

Examination of 125 seed lots by germination in greenhouse flats containing pasteurized soil showed that infection was heavy on several lots from Willamette Valley, Ore., where overhead irrigation of sugar beet seed crops was practiced; light to moderate on seed from Medford, Ore., Shasta Valley, Calif., and St. George, Utah; and extremely light on seed from Hemet Valley, Calif.

Disinfection of sugar beet seed by immersion in a solution of ethyl mercury phosphate was highly effective for elimination of *Phoma* infection.

As dust fungicides, Ceresan and New Improved Ceresan appeared to be the most effective, although Phygon and Arasan also afforded good control.

Disinfection of some *Phoma*-infected seed lots increased their germination on blotters and their emergence in sand and in soil.

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Growing Sugar Beets Following Alfalfa In Montana[1]

H. E. Morris and M. M. Afanasiev[2]

In rotations in which sugar beets are grown as the principal cash crop, alfalfa has an important place. However, many failures of sugar beets have been recorded when alfalfa was the preceding crop. Root rots of sugar beet seedlings have been prevalent in Montana for many years, and this condition usually seems to be more severe when sugar beets immediately follow alfalfa.

The usual procedure in handling alfalfa in the rotation is as follows. The land is shallow plowed (crowned) after the third crop has been removed. From 3 to 4 weeks later, or as soon as the severed roots have dried, the land is plowed to a depth of 8 inches and left rough over winter. In the spring a satisfactory seedbed is prepared by disking, harrowing, and leveling.

Very little if any decomposition of the residual alfalfa material takes place until warm weather occurs, which usually coincides with the germination and early growth of the young beets. Therefore, competition for available nutrients, especially nitrogen, occurs between

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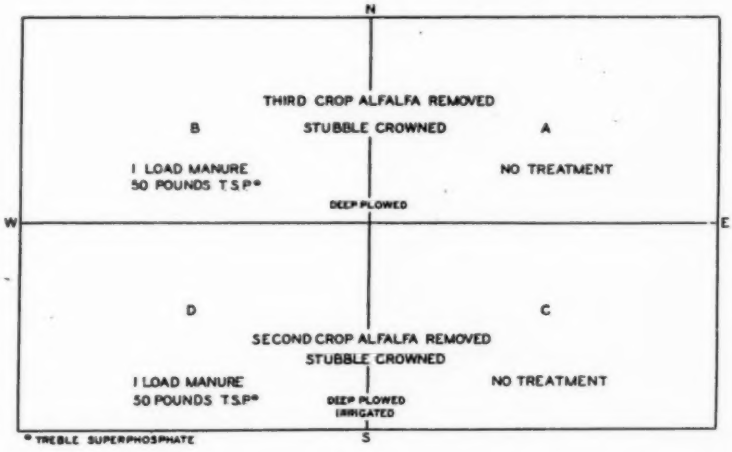

Figure 1.—Different treatments of a 2-year-old alfalfa plot (Rotation 46), Huntley (Mont.) Field Station, 1942-1945.

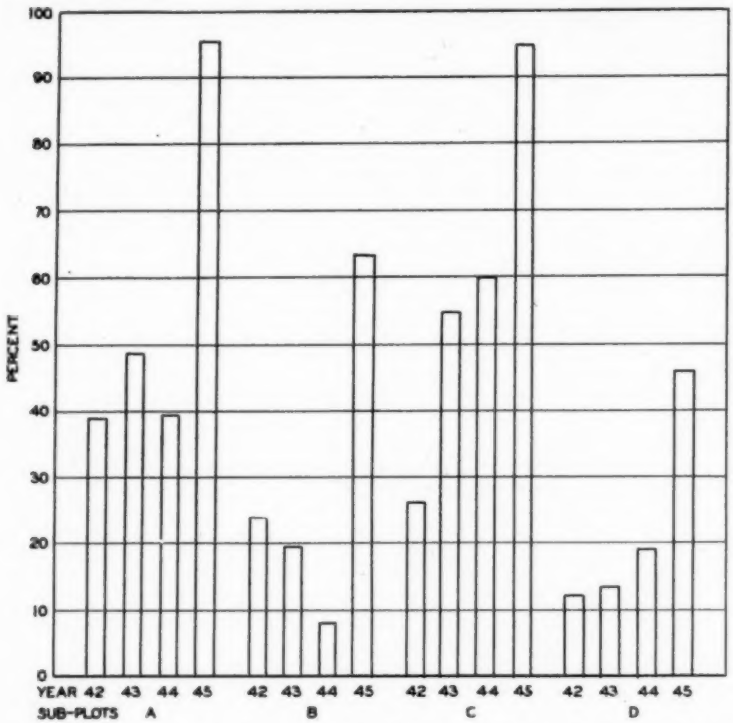

Figure 2.—Seedling diseases of sugar beets on sub-plots A. B. C. D, Rotation 46, Huntley (Mont.) Field Station, 1942-1945.

the young beets and the organisms concerned with decomposition of the organic matter plowed under in the fall.

It is a well-known fact that alfalfa is a heavy feeder on the available phosphorus supply in the soil. It is an equally well-known fact that sugar beets require considerable amounts of available plant food, especially nitrogen and phosphorus, in order to produce strong, vigorous plants resistant to the attack of soil organisms which often cause seedling diseases. Following alfalfa, sugar beets often suffer from a lack of nitrogen in their early stages of growth, and beets grown in unfertilized soil immediately following alfalfa frequently show the characteristic symptoms of phosphate deficiency in mid-season or later.

The importance of handling alfalfa land preceding sugar beets in order to secure good stands and yields of beets was well demon-

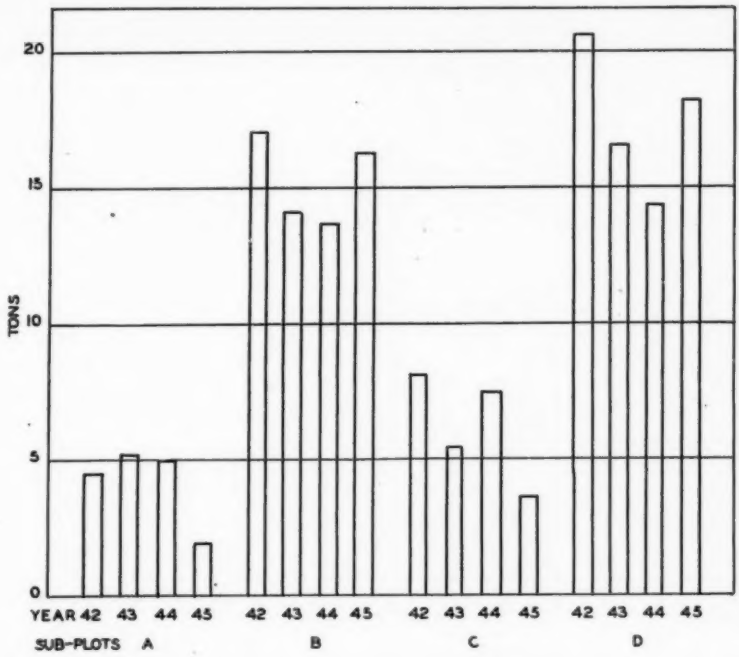

Figure 3.—Yield (tons) of sugar beets on sub-plots A, B, C, D, Rotation 46, Huntley (Mont.) Field Station, 1942-1945.

strated in an experiment started in the fall of 1941, using the plots of Rotation 46 at the Huntley Field Station. This rotation, begun in 1916, consisted of 2 years of alfalfa, sugar beets, and oats in one-fourth-acre plots. For 5 years previous to 1941 the yield of sugar beets in this rotation averaged less than 3 tons per acre. It was often necessary to replant the beet plot largely because of loss of seedlings from root rot which resulted in a poor stand.

In 1941 the one-fourth-acre plot (second year alfalfa) in Rotation 46 was equally divided into four small plots. In sub-plots C and D the alfalfa stubble was shallow plowed after the second crop of hay was removed; treble superphosphate (50 pounds) and manure (1 ton) were applied to sub-plot D, and 2 or 3 weeks later these two plots were plowed and irrigated (figure 1).

The third crop of alfalfa was removed from sub-plots A and B, the stubble was shallow plowed, and treble superphosphate (50

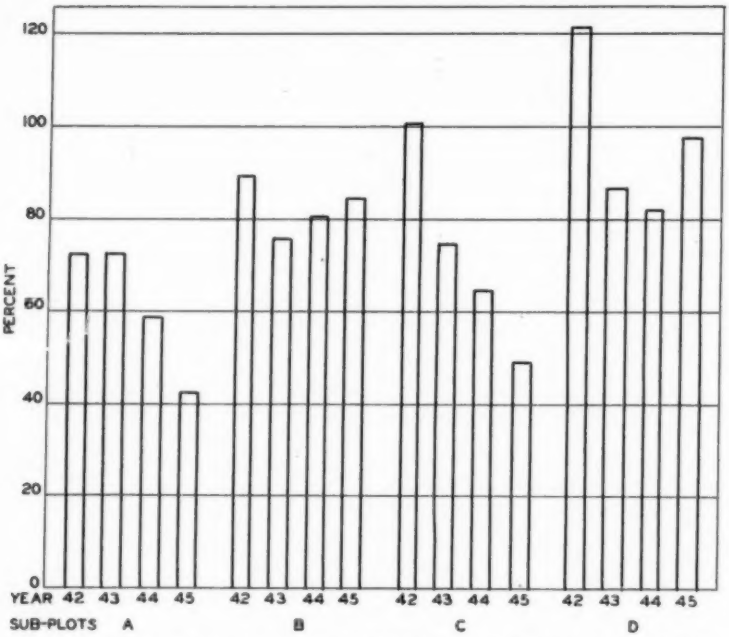

Figure 4.—Stand of sugar beets on sub-plots A, B, C, D, Rotation 46, Huntley (Mont.) Field Station, 1942-1945 (percentage of theoretical stand 26,136).

pounds) and manure (1 ton) were added to sub-plot B, and 2 or 3 weeks later the two plots were deep plowed (figure 1).

In the spring the same cultural procedures were followed on all four sub-plots, and each was planted to sugar beets. During the 3 following years a different plot of Rotation 46 was treated in a similar way.

The yield of beets in tons, the stand, and the amount of seedling diseases in each of the sub-plots, A, B, C, and D, are shown in figures 2 and 4 and table 1.

The results show that the addition of treble superphosphate and manure to the alfalfa soil before the beets were planted was highly beneficial in producing good stands and yields of beets with less seedling disease in comparison with beets planted in unfertilized alfalfa soil.

Low yields in sub-plots A and C each year are explained by the fact that the beets in their early growth had to compete with the organism causing decomposition of the alfalfa residue for their nitro-

Table 1.—Sugar beet sub-plots of Rotation 46, Huntley (Mont.) Field Station.

Plots	1942	1943	1944	1945
	Stand* (percent of theoretical stand 26,136)			
A	72.5	72.7	58.8	42.2
B	89.4	75.7	80.9	85.2
C	101.5	74.6	65.3	49.0
D	121.9	86.7	82.6	97.8
	Seedling diseases† (percent)			
A	38.2	47.2	39.3	94.0
B	23.2	19.7	7.5	62.5
C	26.2	54.5	60.0	94.9
D	12.8	13.9	18.6	56.5
	Yield (tons per acre)			
A	4.40	5.30	5.10	1.93
B	16.88	14.22	13.45	16.17
C	8.11	5.38	7.42	3.43
D	20.48	16.37	14.14	17.94

*Stand determined on thinned beets.
†Seedling diseases determined on unthinned beets.

gen supply, and later in the season they suffered from lack of phosphorus as the alfalfa had used a great deal of the available phosphorus.

Summary

1. The results of this test, which extended over 4 years, show that if sugar beets follow alfalfa the soil should be plowed after the second crop of alfalfa, which should preferably be plowed under, and some additional nitrogen (manure) and phosphorus should be added.

2. After the alfalfa is turned under, irrigation should be used to aid decomposition.

3. The planting of sugar beets on late-fall-plowed alfalfa land, unless manure, nitrogen, and phosphorus are added to the soil, is not recommended because the prevalence of root rots makes it difficult to obtain a satisfactory stand and yield.

Foreign Virus Diseases Potentially Dangerous to the Sugar Beet Industry in the United States

C. W. BENNETT[1]

Five virus diseases, curly top, mosaic, savoy, cucumber mosaic, and yellow vein are known on sugar beets in the United States. Of these, curly top, which occurs in western United States, is by far the most severe, but its destructiveness on sugar beets has been reduced greatly in recent years by the development and use of curly top resistant varieties. Beet mosaic occurs in all parts of the United States where sugar beets are grown. It has not caused serious reduction in yield of beets grown for sugar, but it has been shown (*5*)[2] to be capable of causing appreciable injury to beets grown for seed. Savoy appears to be limited largely to the middle western states. It produces severe injury on plants that are attacked, but fortunately it spreads slowly and few cases of high percentages of infection have been reported. A severe outbreak of cucumber mosaic on sugar beets occurred in the southern part of the San Joaquin Valley in California in 1940, resulting in the abandonment of some fields and in appreciable reduction in yield in other fields. The factors involved in this outbreak have not been determined. Under average conditions the disease is rarely found on sugar beets. Yellow vein is of very minor importance but small numbers of diseased plants are found in fields in Colorado and southern California during most seasons.

In addition to the diseases that already occur in the United States, there are at least three other virus diseases, each capable of causing considerable injury, that have not yet been introduced. These are "sugar beet yellows" which occurs in Europe, "Argentine curly top" which occurs in northern Argentina, and "sugar beet yellow wilt" which occurs in the lower valleys of the Rio Negro and the Rio Colorado of Argentina. The introduction of any one of these diseases into the United States probably would increase the hazards encountered in the production of sugar beets.

Sugar Beet Yellows

The yellows disease of sugar beets has been reported from the British Isles, Belgium, the Netherlands, Germany, Denmark, and

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[2]Italic numbers in parentheses refer to literature cited.

northern France. Certain European writers (*8*, *10*) have stated that the disease occurs or probably occurs also in the United States. These conclusions are based on the fact that Townsend (*11*) mentioned leaf thickening as a symtom associated with beet mosaic and Robbins (*9*) described vascular necrosis in plants affected with beet mosaic. Since beet mosaic does not cause leaf thickening or vascular necrosis, these European investigators concluded that both Townsend and Robbins were working with a mixture of virus diseases, one component of which was sugar beet yellows to which they attributed the observed leaf thickening and vascular necrosis. However, both Townsend and Robbins were working in areas where curly top occurs extensively and its is probable that the leaf thickening and vascular necrosis observed by them were due to curly top or some other factor rather than to yellows. As yet there is no evidence indicating that sugar beet yellows occurs in the United States.

Symptoms.—In the British Isles where yellows is reported (*6*) to have caused considerable loss to the sugar beet crop during the past few years, symptoms of the disease usually do not begin to appear until after the middle of the season. Single plants, groups of plants, or even whole fields begin to yellow. The yellowing occurs on the outer leaves. Even in advanced stages of attack the younger leaves usually remain green and free of signs of the disease. Yellowing begins with the production of chlorotic areas varying in color from pale, watery, or greenish yellow, to orange or even red in certain varieties of beets. The pattern of yellowing varies, but it begins often at the tip of the leaf, extending downward toward the petiole, sometimes avoiding the large veins and producing a type of interveinal mottle. Frequently the chlorotic areas become necrotic and are invaded by fungi. Yellowed leaves are thick and brittle and crackle when broken. Starch accumulates in the affected leaves and gummy deposits occur in the secondary phloem.

Symptoms of yellows are easily confused with yellowing due to too much or too little water, mineral deficiencies, and other nutritional or soil conditions. If infection occurs late in the season, yields are not greatly affected and the yellowing is mistaken often for normal ripening of the crop.

Host Range and Varietal Susceptibility.—Beet yellows has been reported on sugar beet, red garden beet, mangel-wurzel, spinach, and *Beta maritima* L. Apparently the host range of the disease has not been investigated extensively, and it is possible that other kinds of plants may be susceptible. The relative susceptibility of many varieties of sugar beet has been tested in the British Isles. No variety has been found markedly superior to others in resistance, but small differences in susceptibility have been found which indicate that it

may be possible to breed varieties that will be more resistant to the disease than those now available.

Transmission.—Sugar beet yellows virus is not transmissible through seeds and it has not been transmitted by means of sap from diseased plants. Spread under field conditions takes place only through insects, chiefly the green peach aphid, *Myzus persicae* (Sulz.), and the bean aphid, *Aphis rumicis* L. Watson (*12*) has shown that the efficiency of *Myzus persicae* as an agent of transmission increases greatly with increased feeding on diseased plants. The virus is retained for a considerable period by the aphid and a single individual may infect several plants.

The virus overwinters in the roots of escaped plants, in stecklings grown for seed production, and in roots of other susceptible crops where plants survive the winter. Aphids feeding on the new growth of such plants in the spring acquire the virus and carry it to neighboring beet fields.

Probable Results if Sugar Beet Yellows Were Introduced.—In the British Isles where best records are available on the damage sugar beet yellows is capable of causing to sugar beets, injury has varied considerably from year to year. During the war years injury apparently increased and in 1943 losses were severe. Factors most important in determining the amount of disease are aphid populations and migrations and the number of diseased plants of beets and other susceptible crops that survive the winter to serve as a source of spring inoculum. Losses vary with time of infection. Hull and Watson (*6*) estimate that when fields are 100 percent infected in July, reduction in yield of sugar amounts to about 50 percent; whereas, a 100 percent infection in mid-September results in a loss of only 15 to 20 percent in yield of sugar.

On the basis of the known requirements for the production of a severe attack of sugar beet yellows, it seems probable that in those areas of the United States where sugar beets do not readily survive the winter and where plants from the preceding crop would not serve as a source of infection little injury would result from yellows. However, in those areas where wild or escaped beets survive the winter or where plantings are made in th fall, this disease might become destructive. It is worthy of note that this latter area includes all of the locations in New Mexico, Arizona, California, Utah, and Oregon in which sugar beet seeds are produced. Furthermore, under the method of seed production employed in these areas, in which planting takes place in the fall and harvesting the following summer, the crop grown for seed would be subject to infection in the fall, the plants would carry the rivus through the winter, and spread would con-

tinue in the spring. In those areas where aphids are active throughout the year, probably some infection would occur even during the winter months.

In the California seed-producing areas living plants are available to harbor the virus throughout the year. Wild or escaped beets occur along irrigation ditches and roadsides, seedlings develop after harvest of the seed crops, and frequently growth from the stubble of the seed crop develops and lives through to the following year. Infected plants of these types would serve as excellent sources of infection for the plantings made in the fall for the seed crop of the following year. It is worthy of note that such material has harbored enough virus to produce very high percentages of mosaic in the seed crop during recent years. Since mosaic and yellows are spread by the same two species of aphids, it seems probable that conditions that result in a high percentage of infection by yellows if the latter virus should become established. It seems probable, therefore, that introduction of sugar beet yellows into the United States would result in considerable loss to the industry and that the disease might develop into a major problem in the sugar beet seed industry.

Argentine Curly Top

Argentine curly top was first described by Fawcett (*4*) in 1925 in experimental plots of sugar beets grown at the Estacion Experimental Agricola de Tucuman in the province of Tucuman, Argentina. There is evidence (*2*) that the disease occurs also in the Rio Negro Valley in central Argentina. Sugar beets have never been grown commercially in the province of Tucuman where the disease was first discovered, but European varieties appear to have been injured to an appreciable degree in the plots where the disease was first discovered. So far as known, conditions have not been favorable for serious spread of the disease in the Rio Negro Valley where sugar beets were grown commercially from 1929 to 1940. There is no report of the disease from the sugar beet producing area of Uruguay.

Symptoms.—Sugar beets may be attacked by Argentine curly top at any stage in their development. Soon after plants are infected the young leaves begin to curl, the veins become translucent, and the petioles are somewhat shorter than normal. Sometimes, especially in the earlier stages of the disease on rapidly growing plants, drops of sugary exudate that soon turn black appear on the diseased blades and petioles. In later stages, veins of mature leaves of the more susceptible varieties are swollen and irregular and often have protuberances and spiny outgrowths. Transverse sections of diseased petioles and roots often show dark areas in the veins due to necrosis of the phloem.

The first symptoms are the most severe and plants tend to recover from the more severe initial symptoms as they continue to grow. The more resistant varieties recover almost completely, even when infected in the seedling stage, and the more susceptible varieties improve markedly.

Symptoms produced by Argentine curly top are very similar to those produced by North American curly top. The chief difference between the two diseases lies in the greater tendency of plants affected by Argentine curly top to recover from the more severe effects of the disease. Because of this characteristic the Argentine curly top would be expected to have less effect on yield than North American curly top.

Host Range and Varietal Susceptibility.—Argentine curly top has been found occurring naturally on sugar beet, mangel-wurzel, and red table beet. It has been found also on petunia (X *Petunia hybrida* Vilm.) and a species of groundcherry and has been transmitted experimentally to chickweed (*Stellaria media* (L.) Cyr.) and zinnia (*Zinnia elegans* Jacq.). Apparently it does not attack tomatoes or tobacco and limited inoculation tests have failed to produce infection on beans. The causal virus probably has weed host plants in Argentina from which the disease spreads to beets but these have not yet been determined.

Varieties of sugar beets tested under field conditions at Tucuman in the season of 1940-41 showed marked difference in susceptibility to the disease. Varieties S.L.[3] 842 and R. and G. Old Type, both known to be very susceptible to North American curly top, were found susceptible to Argentine curly top. Varieties U. S. 11[3], U. S. 12, and S.L. 68, all restistant to North American curly top, were resistant also to Argentine curly top.

Transmission.—Argentine curly top is transmitted by a leafhopper, *Agalliana ensigera* Oman, which appears to have been reported only from Argentina.

This leafhopper thrives on sugar beets and closely related plants and may reach high population levels on these plants under field conditions. It acquires the curly-top virus by feeding on diseased plants; after the virus is acquired the insect retains it for long periods, probably for the remainder of its life, even though it may not again feed on a diseased plant. A single individual may produce infection

[3]Varieties released for commercial use by the Bureau of Plant Industry, Soils, and Agricultural Engineering are designated as "U. S." varieties. "S. L." refers to varieties maintained at the U. S. Sugar Plant Field Laboratory at Salt Lake City, Utah.

on a number of different plants. The beet leafhopper, *Eutettix tenellus* (Bak.), vector of North American curly-top virus, is unable to transmit the Argentine virus.

Probable Results if Argentine Curly Top Were Introduced.—Evidence indicates that it would be necessary to introduce both the causal virus and the insect vector in order for Argentine curly top to become established here, since neither the leafhopper nor the virus now occurs in the United States. After introduction, the area over which the disease could spread would depend largely on the range of environmental conditions under which the leafhopper vector would be able to survive, assuming of course that there are no other insects able to transmit the disease. The amount of infection would depend largely on the leafhopper population and on the number and character of host plants of the virus from which the disease could spread to commercial plantings. Although the information on these points is limited, it may be sufficient to justify a certain amount of speculation.

The leafhopper vector, *Agalliana ensigera*, has been reported (7) from localities well distributed over northern and central Argentina. The range of climatic conditions in this area does not differ greatly from that encountered over the whole of the United States except that in Argentina there is no region of cold winters and high rainfall comparable to our northeastern and middle western states. It might be expected on the basis of the distribution of the insect in Argentina that it could survive in most of the western and southern parts of the United States. Thus Argentine curly top might be expected to spread over most of the area where North American curly top does not now occur or is found rarely. However, injury from this disease would be greatly minimized because varieties of sugar beet resistant to North American curly top are now grown over much of this area where sugar beets are produced and there is reason to believe that all or most of these varieties are resistant also to Argentine curly top.

Yellow Wilt

In recent years several atempts have been made to establish a beet sugar industry in Argentina. The most important of these occurred in the lower part of the Rio Negro where a factory was built and began operation in 1929. This part of Argentina has a fertile soil, an abundant supply of water for irrigation, and a favorable climate for sugar beets. It was found that beets thrived in the early part of the season but later many plants either turned yellow and ceased to develop normally or wilted and died because of a disease now known as yellow wilt. In 1937-38 and in 1938-39 the disease reached

a peak of severity in the plantings of the Rio Negro Valley and was responsible for an almost complete loss of the crop. It caused serious injury also in small plantings in the valley of the Rio Colorado about 90 miles to the north. In 1941, sugar beet growing in the Rio Negro Valley was abandoned because of the inroads of this disease, and the factory was dismantled and sold. The disease, so far as known, has not yet spread to any other beet-growing areas.

Symptoms.—Two rather distinct phases of yellow wilt have been described (*3*) on sugar beets in the Rio Negro Valley of Argentina. One is characterized by yellowing and stunting and the other by rapid wilting and death.

The disease does not begin to appear extensively in the field until the plants are well advanced and have roots an inch or more in diameter. Usually the most obvious symptoms on plants attacked early in the season consist of yellowing and stunting. Leaves have irregular edges, are rolled upward and inward, and are thick and brittle. Some of the outer leaves die; others appear scorched along the edges and between the larger veins and stand more nearly vertical than those of normal plants. Sometimes the vein pattern is clearly evident because of continuous or broken yellow lines along the medium-size veins. Frequently there is a tendency toward stimulation of growth of axillary buds, giving the plant a bunchy appearance. Roots become tough and woody and sometimes the tip portion dies and lateral roots develop. Successive crops of rootlets are produced and die, resulting in a tufted condition along the lines of sutures where rootlets are produced. Plants may live throughout the season but they grow very little after becoming diseased.

Plants attacked later in the season when temperatures are higher and transpiration rates greater often wilt rapidly and die. Frequently large vigorous plants begin to wilt about midday and by late afternoon the leaves droop markedly. During the night plants recover partially but the following day they usually wilt so much that the outer leaves lie flat on the ground. Often within a week all of the older leaves are scorched and dead. In some plants the small central leaves recover somewhat following the death of the larger leaves and produce some additional growth but such leaves are small, thick, folded, and greenish yellow, sometimes slightly tinged with purple. Roots wilt from the tip upward, shrink, and decay. Plants in stages intermediate between yellowing and wilting occur in most fields.

Usually by mid-season diseased fields have high percentages of the plants yellow, wilted, or dead (**figure 1**).

Figure 1.—Field of sugar beets in the valley of the Rio Negro in Argentina, showing damage produced by yellow wilt. Many plants are yellow and dwarfed, others are dead, and still others are badly wilted. A few plants are still healthy. Photographed February, 1941.

Host Range and Varietal Susceptibility.—In the valley of the Rio Negro yellow wilt has been important chiefly as a disease of the sugar beet, but it is capable of causing severe injury also to red table beets (*Beta vulgaris*) and to Swiss chard (*Beta vulgaris* var. *cicla* L.). The causal virus probably is indigenous to this part of Argentina. It probably occurs in desert species of plants which may serve as the chief sources of spread of the disease to sugar beets.

There is no evidence that any variety of sugar bet has an appreciable amount of resistance to yellow wilt. In the season of 1938-39, Carlos Munck (*3*) tested 20 European varieties and 2 varieties from the United States (U. S. 12 and U. S. 33) for resistance to this disease. Large percentages of all varieties were killed and there was no evidence that any one variety was superior to others. The test was repeated in the season of 1939-40 with results similar to those obtained the previous season. Extensive selections were made from plants surviving these tests in an effort to increase resistance. The progeny from these selections showed no greater resistance, however, than that possessed by the varieties from which the selections were made.

Transmission.—Yellow wilt is not transmissible by inoculation with juice from diseased plants. It has been transmitted by graft and by two species of dodder, *Cuscuta subinclusa* D. & H. and by *C. campestris* Yuncker. Under field conditions in Argentina it ap-

pears to be spread by a leafhopper, *Atanus exitiosus* Beamer, which was described (*1*) as a new species from specimens collected in the Rio Negro Valley in 1941. Very little is known regarding the life history, distribution, and host plants of this insect, but it is known to be able to live and reproduce on sugar beets.

Probable Results if Yellow Wilt Were Introduced.—Of all the foreign virus diseases of sugar beet, yellow wilt probably constitutes the greatest potential threat to the sugar beet industry. To determine accurately the area over which the disease would spread in the United States and the amount of damage it likely would cause, a greater amount of information is needed regarding the host-plant and climatic requirements of the insect vector or vectors and on the number and distribution of susceptible non-cultivated and crop plants that would serve as sources of virus for spread to beet fields. The evidence now available indicates that certain areas in western United States where sugar beets are grown extensively would be most severely affected. The Rio Negro Valley of Argentina where this disease now occurs is a region of light rainfall and relatively low winter temperatures. Since *Atanus exitiosus*, the probable insect vector, thrives there it seems reasonable to expect that it would do well also in parts of the United States having a similar climate. It seems certain that in any area where the disease could become as destructive as it has been in Argentina its introduction would result in abandonment of the industry, at least until varieties more resistant than those now known could be found or developed. The threat is more serious because no appreciable resistance to the disease has been found in any of the many sugar beet varieties tested. Production of resistant varieties might require a long and complicated program of selection and breeding. It seems possible, therefore, that introduction of yellow wilt into the United States might prove to be a major catastrophe to the sugar beet industry.

Summary

Three foreign virus diseases, each capable of causing appreciable injury to sugar beets, are known. These are "sugar beet yellows" in Europe, "Argentine curly top" in Argentina, and "yellow wilt" in the Rio Negro Valley of Argentina.

Sugar beet yellows in recent years has caused considerable loss to sugar beets in the British Isles. Probably in the United States it would cause injury in all areas where beet plants survive the winter to serve as a source of infection for the spring crop. This would include all of the acres where beet seeds are produced.

Argentine curly top in most respects is similar to North American curly top. However, it is spread by a different leafhopper vector, it

apparently is unable to attack tobacco and tomatoes, and infected beet plants tend to recover to a greater degree than from North American curly top. Certain varieties resistant to North American curly top are resistant also to Argentine curly top and it seems probable that the varieties that have been produced to resist attacks of North American curly top would provide a high degree of protection against Argentine curly top.

Yellow wilt probably is potentially the most dangerous of these three virus diseases. In the Rio Negro Valley it was extremely destructive over a period of about 10 years and was responsible for abandonment of the sugar beet industry in that region. Rather extensive areas in western United States have climatic conditions similar to those in the Rio Negro Valley. In these areas the disease might become very destructive. The threat is made more serious by the fact that rather extensive tests in Argentina have revealed no varieties of sugar beet resistant to this disease.

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Sugar Beet Varieties in Relation to Curly Top Virus Strains

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The first work with curly top virus strains was prompted by the variable results obtained from inoculations of the sugar beet varieties Old Type and S.L. 68. Some strains of the virus were soon separated (*1*)[2] and it was found that the variety Old Type was equally susceptible to strains 1 and 3 but that the variety S. L. 68, while fairly resistant to strain 1, was practically immune to strain 3. The comparative symptoms induced on S.L. 842, which is equivalent to Old Type in susceptibility, and on S.L. 68 are shown by figures 1 and 2. These two beet varieties showed a similar difference in response to some other virus strains but the difference for strains 1 and 3 was far more striking than any others.

Figure 1.—Beet S.L. 68 infected with curly top virus strain 1. The plant with curled leaves, in foreground, would be graded 2 in severity of symptoms and the others 1 or 1.5. Photographed 30 days after inoculation.

The reactions of beet varieties to different virus strains have been tested at frequent intervals during the past 12 years. All European varieties which have been tested and the earlier commercial varieties of American origin were quite susceptible to both strains 1 and 3. Only the more recently developed varieties and breeders stocks show a truly high degree of curly top resistance and a tendency toward complete immunity against some of the strains.

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[2]Italic numbers in parentheses refer to literature cited.

Table 1.—Response of beet varieties to curly top virus strains. Tests of September-November 1940.

Virus strain	Sugar beet variety											
	S.L. 842 Diseased		U.S. 15 Diseased		U.S. 33 Diseased		U.S. 22 Diseased		A-600 Diseased		S.L. 68 Diseased	
	Pct.	Severity	Pct.	Severity	Pct.	Severity	Pct.	Severity	Pct.	Severity	Pct.	Severity
1	100	3.0	100	2.1	88	2.1	100	1.9	100	2.0		
2	90	2.0	82	1.7	75	1.2	71	1.3	58	1.1	68	1.0
3	100	3.4	65	1.2	0	.0	0	.0	0	.0		
4	90	2.0	82	1.8	75	1.3	63	1.0	67	1.0	10	1.0
5	88	2.2	83	2.2	75	1.3	73	1.0	52	1.0	5	1.0
6	95	2.4	92	2.2	75	1.9	73	1.2	33	1.0	16	1.0
7	85	1.0	75	1.4	50	1.0	13	1.0	0	.0	0	.0
8	85	4.6	75	3.6	92	2.7	13	1.7	33	1.6	0	.0
9	100	4.9	100	4.3	92	3.3	100	1.8	33	1.3	25	1.0
10	92	2.0	82	1.5	92	2.0	0	.0	17	1.0	0	.0

In table 1 are given the results of one group of tests conducted in 1940. The severity of symptoms is indicated by the figure under the subhead "Severity". Plants showing no symptoms are marked .0, while those with most severe symptoms are graded 5. The S.L. 842 beets shown in figure 1 would be graded 5 while some of the S.L. 68 would be graded 1 and one of them, with curled leaves, would be graded 2. The severity figures given in tables are averages for a group of plants. Among the varieties listed in table 1 it would appear that U. S. 22 and A-600 were about equal in resistance, while U. S. 33 was distinctly better than U. S. 15 and the latter was much superior to S.L. 842. The non-commercial variety S.L. 68 showed the highest resistance of any.

The results of some tests during 1945 are given in table 2. These tests indicate some improvement in U. S. 22, and the breeders stocks

Table 2.—Response of beet varieties to curly top virus strains. Tests of August-September 1945.

Virus strain	Sugar beet variety									
	Diseased S.L. 842		Diseased U.S. 22		Diseased S.L. 68		Diseased S.L. 5445		Diseased S.L. 5459	
	Pct.	Severity	Pct.	Severity	Pct.	Severity	Pct.	Severity	Pct.	Severity
1	100	3.0	100	2.1	88	2.1	100	1.0	100	2.0
2	100	2.0	90	1.2	50	1.0	88	1.9	100	1.0
3	100	3.4	65	1.2	0	.0	0	.0	0	.0
4	100	2.0	65	0.9	71	0.9	63	1.0	100	1.0
5	100	3.7	94	1.0	38	1.0	88	1.0	75	1.0
6	100	2.3	80	1.0	56	0.9	88	1.0	88	1.0
7	100	1.1	65	1.0	0	.0	63	1.0	75	0.7
8	100	3.8	20	1.0	0	.0	25	0.8	0	.0
9	100	4.8	55	1.4	50	1.0	100	1.0	100	1.0
10	75	2.0	5	1.0	0	.0	0	.0	0	.0

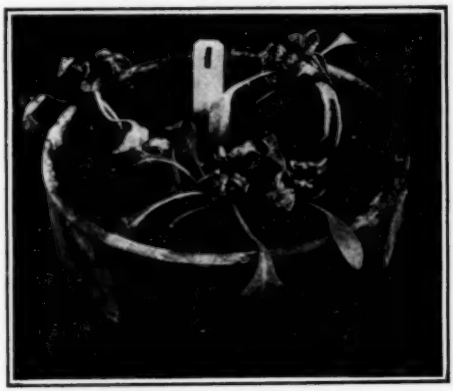

Figure 2.—Beet S.L. 842 infected with curly top virus strain 1. These would all be graded 5 in severity of symptoms. S.L. 842 plants infected with strain 3 show symptoms indistinguishable from this.

S.L. 5445 and 5459 show very nearly the same degre of resistance as S.L. 68. It has been shown repeatedly that curly top virus strain 3 does not survive in large plants of the variety S. L. 68 even when colonies of 100 or more viruliferous leafhoppers are maintained on them for several weeks. Recent tests indicate that breeders stocks S.L. 5445 and 5459 also are practically immune to virus strain 3 and, if the plants are immune, there is no multiplication of the virus in them. Table 2 shows that there was no infection of the young plants of S.L. 5445 or S.L. 5459 by either strain 3 or strain 10 and beet varieties which are so highly resistant to strain 3 also show high resistance to strains 5, 6, 8, and 9 which cause severe injury or death to infected susceptible beets. Results obtained from other experiments (*2*) would certainly suggest that the amount of concentration of any curly top virus strain is doubtless much lower in these highly resistant breeders stocks than in more susceptible varieties.

As these recently developed curly top resistant breeders stocks are released and come into widespread use it seems to me that there is good reason to believe that there will be a pronounced decrease in the prevalence of some of the strains of curly top virus which cause so much injury to beets and to other crops.

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Sugar Beet and Curly Top History in Southern Idaho 1912-1945

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Sugar beets were first grown in the Burley area of southern Idaho in 1912 and in the neighboring Twin Falls area in 1916. Average yields in the first 7 years ranged from 7.21 to 11.33 tons per acre. Curly top probably was not a major factor in those early years and the gradual rise in average yields likely was due mainly to increasing experience in handling the crop. Sugar beet growing in southern Idaho expanded rapidly in 1916, 1917, and 1918 under the stimulus of the sugar shortage resulting from World War I. This expansion was abruptly checked by the first very severe curly top outbreak in southern Idaho which occurred in 1919. Good and bad years followed in about equal numbers until curly top resistant varieties came into general use in 1935.

Curly Top Control Measures

Curly top control measures available before resistant varieties were developed were of relatively little value. Early planting and good cultural care to get the beets advanced as much as possible before the beet leafhopper invasion occurred was generally recommended. Forecasts by the Bureau of Entomology, U. S. Department of Agriculture. (*1*)[2] of probable leafhopper abundance and the consequent variation in amount of curly top damage encouraged or discouraged the planting of sugar beet acreage to a degree that was generally beneficial.

Control of curly top by the use of resistant varieties began with the release of the variety U. S. 1. This variety suffered damage in years of drastic curly top exposure, but it averaged high enough in resistance so that a great advance was made with it toward satisfactory curly top control. U. S. 1 was soon superseded by the variety U. S. 34 which was in turn replaced by A-600, a variety developed by the Amalgamated Sugar Company, and U. S. 12. Later U. S. 22, a high-yielding variety with very high curly top resistance came into general use. Sufficient seed of U. S. 22 was available to plant the entire sugar beet acreage of southern Idaho in 1942. A yield of 16.84 tons per acre from 21,762 acres, was obtained with U. S. 22 in 1942.

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[2]Italic numbers in parentheses refer to literature cited.

Table 1.—Sugar beet yield data for southern Idaho for the period 1912-1945*

Year	Acres planted	Acres harvested	Acres abandoned	Tons harvested	Harvested acre yield
1912†	3,404	2,936	468	21,171	7.21
1913	5,057	4,389	668	36,889	8.40
1914	4,977	4,760	217	49,654	10.43
1915	8,391	8,110	281	86,454	10.66
1916	14,223	11,681	2,542	120,264	10.30
1917	9,680	8,622	1,058	88,535	10.27
1918	6,885	6,045	840	68,484	11.33
1919	19,182	12,942	6,240	82,214	6.35
1920	15,540	13.332	2,208	130,737	9.81
1921	17,869	15,086	2,783	137,119	9.09
1922	8,891	7,591	1,300	95,998	12.65
1923	15,856	15,691	165	206,478	13.16
1924	22,418	10,976	11,442	60,485	5.51
1925‡		11,159		135,702	12.16
1926	7,131	2,119	5,012	12,790	6.04
1927	10,728	9,845	883	147,075	14.94
1928	1,965	1,828	137	20,152	11.02
1929	15,872	13,467	2,405	166,476	12.36
1930	11,862	9,358	2,504	87,784	9.38
1931‡		4,291		38,305	8.93
1932	14,536	14,517	19	234,434	16.15
1933‡		25,612		353,033	13.78
1934	21,389	2,754	18,635	13,451	4.88
1935	10,552	10,440	112	144,410	13.83
1936	23,966	22,322	1,644	302,403	13.55
1937	21,568	20,755	813	245,993	11.85
1938	28,068	26,841	1,227	432,216	16.10
1939	26,783	25,535	1,248	394.601	15.45
1940	26,511	25,345	1,166	439,803	17.35
1941	22,005	21,418	587	288,126	13.45
1942	22,386	21,762	624	366,554	16.84
1943	12,440	9,947	2,493	175,974	17.69
1944	14,618	12,332	2,286	197,178	15.99
1945	17,228	15,528	1,700	253,841	16.35

*In 1936 the Twin Falls factory district took in new territory on the north side of the Snake River (Gooding and Lincoln Counties) which are relatively low-yielding areas.

†1912 to 1915 for the Burley-Rupert district only.

‡Figures for acres planted are lacking.

Acreage and Yield Records

The historical records summarized in table 1, showing average yields of sugar beets per acre in southern Idaho and the total acreages planted and harvested, reveal some important relationships. The significance of the low average yields per acre in the years of heavy curly top damage becomes greater when the fact is noted that in those same seasons the acreages abandoned between planting time and harvest ran comparatively high. For example, in the good year 1923 only 165 acres or 1 percent of 15,856 acres planted was lost be-

fore harvest, while in the bad year following, 1924, there were lost or abandoned between planting time and harvest, 11,442 acres or 51 percent of the total of 22,418 acres planted. Such figures taken in connection with the average yields per acre, 13.16 tons in 1923 and 5.51 tons in 1924, afford a better appreciation of the enormity of the losses sometimes caused by curly top during the period before resistant varieties were available.

The tabulated data also indicate for the earlier years the normal tendency of growers to be discouraged and plant less acreage to beets in the season following a bad curly top outbreak and to expand the acreage in seasons following good years. Noteworthy exceptions occurred beginning in 1927. The season of 1926 had a disastrous curly top outbreak, but the acreage planted in the following season, 1927, was increased by 3,587 acres, the increases in the Twin Falls area being slightly more than 100 percent. The explanation is that the Bureau of Entomology leafhopper forecast was favorable and growers were encouraged therefore to plant beets. An unfavorable forecast was issued in 1928 and even though fine yields had been obtained in 1927, the acreage planted to beets was drastically reduced. In 1928 in the Twin Falls area, 333 acres were planted as compared with 6,940 in the preceding season. Table 1 also reveals that the acreage planted and the average yields tended to become stabilized after resistant varieties came into general use in 1935.

The graph of average beet yields in figure 1 indicates that there were noteworthy drops in yields in 1937 and 1941. The spring leafhopper population in the beet fields was very large in 1937 (*3*). The spring population was not quite so large in 1941 but the invasion was earlier (*2*). The fact that the average yield was lower in 1937 may have been due in part to the fact that the varieties in use that year were not on the average as highly resistant as those in use in 1941. Curly top damage would probably have been very great in both years if resistant varieties had not been in use. The two best years before resistant varieties became available, 1927 and 1932, did not give average yields as high as the three best years, 1940, 1942, and 1943, after resistant varieties came into use.

Improvement and Stabilization

The stabilization of sugar beet growing in southern Idaho following the introduction and improvement of resistant varieties can be better understood by noting the progress indicated by the comparisons of Old Type, the European variety formerly used widely, and the U. S. curly top resistant varieties which superseded it. The data are shown in table 2. Comparison is also shown in the figure 2.

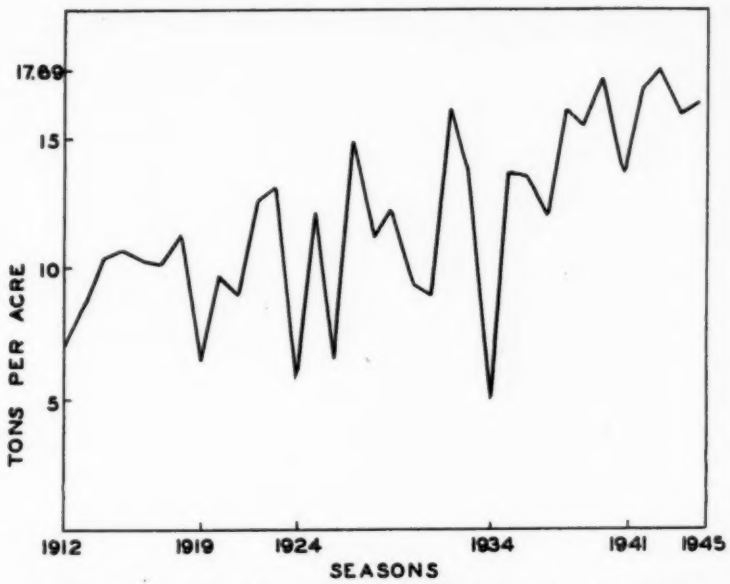

Figure 1.—Average yields of sugar beets per acre in southern Idaho, 1912-1945.

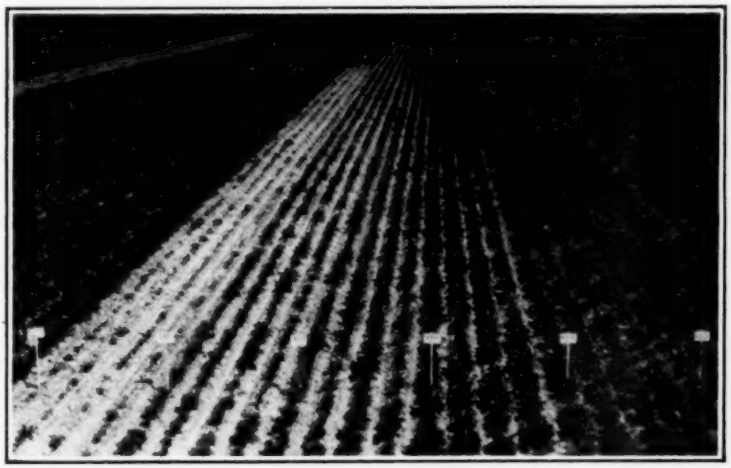

Figure 2.—Sugar beet varieties in breeding field near Buhl, Idaho. Four-row plots, left to right: Old Type, U.S. 1, U.S. 33, U.S. 12, U.S. 22 first release, U.S. 22 second release. Another strip of very badly damaged Old Type in background at left. Planted May 1, 1941. Photographed August 6, 1941.

Table 2.—Yields in tons per acre of a susceptible European variety and resistant U. S. varieties under severe curly top exposure r t Buhl, Idaho. Planted May 1, 1941.

Variety	Tons per acre
Old Type	0.00
U. S. 1	6.31
U. S. 33	8.40
U. S. 12	11.25
U. S. 22	14.32
U. S. 22, 2d. release	16.61

Breeding Better Varieties Continues

Further improvement of sugar beet varieties for southern Idaho and elsewhere has been made. An extremely high degree of curly top resistance has been obtained and by breeding methods is being combined with other improved characteristics. It can be confidently predicted that if other factors are as favorable as the inherent qualities of the beets the trend of average sugar beet yields in southern Idaho will continue upward during the next decade.

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Sugar Beet Nematode (*Heterodera Schachtii*) Control Studies in Ontario

H. L. Fletcher[1]

The sugar beet nematode *(Heterodera Schachtii)* was first reported in Ontario in 1931 by Brown (*1*).[2] The infested area was located near Glencoe. This field was not planted again with sugar beets until 1941. Some nematode-infested spots were observed that year. In 1939 a heavy infestation of the nematode was observed in the Marl soil area near Sarnia. In 1940 there were 40 acres of sugar beets in this region infested with this microscopic nematode.

This Marl soil region formerly was a lake bottom. It consists of approximately 15,000 acres. The principal crops are sugar beets and potatoes. In 1945 this area averaged 12.9 tons of sugar beets per acre. The Ontario average in 1945 was 9.3 tons per acre.

1944 Experiments

In the spring of 1944, Brown[3], McKenzie[4], and Baker[5] inaugurated a set of plots at Albert Leugs' farm, Blackwell, Ontario. This farm, according to the Dominion Department of Entomology survey conducted in 1939 and 1940, had the highest nematode population per acre of all the farms surveyed in the Marl soil district. The purposes of the plot studies were to note the effect of chloropicrin and dichloropropane-dichloropropylene mixture (commonly called D-D) on the growth of sugar beets and the depressing effect of these chemicals on the nematode activity. Fifteen plots, each consisting of 200 square feet, were installed at the Leugs farm. Five plots were selected at random and treated with 2½ cc chloropicrin per square foot. Five plots selected at random were given 2½ cc applications of the D-D mixture. A Larvejector was used to apply the chemicals into the soil. The results obtained from this experiment are listed in table 1.

The results from these experimental plots showed that the D-D mixture apparently had more promising nematocidal properties than chloropicrin.

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[1]Agriculture Research Director, Canada and Dominion Sugar Company, Chatham, Ontario.

[2]Italic numbers in parentheses refer to literature cited.

[3]Brown, H. D. Formerly Chief Agriculturist and Research Director, Canada and Dominion Sugar Co., Chatham, Ontario.

[4]McKenzie, W. A. Technical Promotion Department, Fertilizer Division, Canadian Industries Limited, Chatham, Ontario.

[5]In charge Nematode Investigations, Dominion Department of Entomology, Ottawa, Canada.

Table 1.—Sugar beet nematode control experiments, Blackwell, Ont., 1944. Plots treated May 26, planted June 8, harvested October 16. Seed used: Imperial No. 40. Fertilizer applied: 200 pounds acre 2-16-4.

Treatment	Ave. stand per plot	Mean yield (Tons per acre)
Control	20	0.72
Chloropicrin	40	4.96
D-D mixture	60	3.98

1945 Experiments

To study further the nematocidal properties of D-D mixture along with other soil fumigants was the basis of the 1945 experiments.

The area selected for these experiments was on the Leugs farm and adjacent to the 1944 plots. This area had been in sugar beets in 1944. It showed a high nematode *(Heterodera Schachtii)* cyst population of 2,529,500,000 per acre and an average cyst population of 837,000,000 per acre.

Chemicals Applied

Five compounds and mixtures of compounds were selected for the experiment.

1. Shell Oil Company's crude D-D mixture (2 parts 1-3 dichlorophopylene, 1 part 1-2 dichloropropane, 1 part 3-carbon-atom compounds of trichlorides and tetrachlorides).

This D-D mixture was applied at the rate of

A. 4 cc per square foot
B. 8 cc per square foot
C. 12 cc per square foot
D. 16 cc per square foot

2. Propylene dichloride 12 cc per square foot.

3. A mixture by weight consisting of 80 percent ethylene dichloride and 20 percent propylene dichloride applied at the rate of 12 cc per square foot.

4. 666-benzene hexachloride. Applied at the rate of 1 gram per square foot.

Each treatment was replicated five times. This made 40 plots in all. Each plot was 10 feet by 10 feet. Four-foot alleyways surrounded each plot. The plots for each type of treatment were chosen at random.

An unique technique for applying the liquid chemicals was devised. The Larvejector had not proved to be a very satisfactory instrument for applying fumigants to the soil. Considerable trouble was experienced with the tubes clogging and considerable time was required to treat each plot. A continuous flow dispenser was made by equipping a 1,000-cc Florence flask with a small aperture delivery

tube and an air vent. Long handled hoes were used to make trenches 4 inches deep. Seven trenches were made in each plot. A large spike 8 inches long and 1 inch in diameter was used to punch a series of holes along the bottom of each trench. The quantity of liquid chemical necessary to treat the plot was measured into a graduated cylinder, poured into the Florence flask, and distributed evenly along the trenches. This gave 0 to 12 inches penetration of chemicals. After the treatments were applied, long handled hoes were used to scrape the soil back into the trenches.

The ordinary farming practices were carried on after the treatments were applied. These plots received the same cultural practices employed by Mr. Leugs throughout his entire sugar beet field. At harvest time the sugar beets in each plot were lifted with a spade, topped with a knife, cleaned free of soil, and weighed.

The data obtained are listed in table 2.

Table 2.—Sugar beet nematode control experiments, Blackwell, Ont., 1945. Plots treated May 31, planted June 20, harvested November 7. Seed used: U. S. 215-216 segmented. Fertilizer applied: 200 pounds per acre 2-16-6.

Treatment	Rate of treatment per square foot	Stand	Yields per acre	Sugar in beets	Coef. of purity	Gross sugar per acre
		Percentage	Tons	Percentage	Percentage	Pounds
Control		73	4.70	16.6	83.5	1,560
P	12 cc	66	3.88	16.8	85.1	1,304
PE	12 cc	71	5.40	16.4	83.0	1,771
666	1 gram	68	3.97	16.7	83.1	1,326
DD	4 cc	73	7.97	17.1	84.8	2,726
DD	8 cc	80	9.41	17.6	86.9	3,242
DD	12 cc	73	9.67	17.2	85.8	3,326
DD	16 cc	80	9.10	16.7	87.3	3,039

The field observations made throughout the season indicated that the D-D mixture would give the largest yields per acre. The D-D treated plots were prominently marked off by the effect of the nematodes on the sugar beets in the alleyways.

All sugar beets harvested in every plot had a large number of cysts adhering to the hair rootlets. No fumigant gave a complete kill of *(Heterodera Schachtii)*. The D-D mixture when applied at the rate of 12 cc per square foot appeared to be the most favorable treatment for depressing the nematode activity and increasing the yield of sugar beets in the Marl soil district.

The experimental study is a joint investigation carried on by the Dominion Department of Entomology, Canadian Industries Limited, and Canada and Dominion Sugar Company.

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MACHINERY

1945 Sugar Beet Planter Investigations at Fort Collins, Colo.

S. W. McBirney[1]

The work of the Division of Farm Power and Machinery, U. S. Department of Agriculture and the Colorado Agricultural Experiment Station at Fort ollins, Colo., during the spring of 1945 on sugar beet planter development was planned and carried on with two distinct objectives. One was a study of those characteristics of planters which affect seedling distribution in the field stands; for this work seed furrow openers, press wheels, and other things which affect field germination were kept as nearly constant as possible. The other was a study of those planter characteristics which affect field germination; in this case the planter distribution characteristics were kept the same. Improvements in both seedling distribution and field germination were desired.

Seedling Distribution Characteristics of Planters

The plots planted to compare planter distribution were put in on May 3 and 4 and included 45 different plantings with different planters and equipment and different seeding rates. The soil moisture at planting time was excellent and continued to be so throughout the spring. The summarized results are expressed in terms of the percentage of beet seedlings which are singles, a single being a seedling which is single within a 1-inch length of beet row. This method of evaluation of planter seedling distribution is explained in my accompanying paper entitled "Evaluation of Field Test Data for Comparisons of Sugar Beet Planters."

The data taken from the germination stand counts on this planting were worked up and the percentage of single seedlings have been adjusted for direct comparison as explained in the paper. The percentage of singles was first adjusted to the 35.6 average percent of potential germination and then to the 23.4 average seedling stand per hundred inches, which is the stand for about a 4 pound per acre seeding rate with 20-inch rows. In most cases the adjustments were small since the variations were not great. The summarized percentages of single seedlings are therefore directly comparable where the seed sizes are the same.

The summarized results from this planting are shown in table 1 and are shown by planters with different equipment and with differ-

[1]Bureau of Plant Industry, Soils, and Agricultural Engineering U. S. Department of Agriculture.

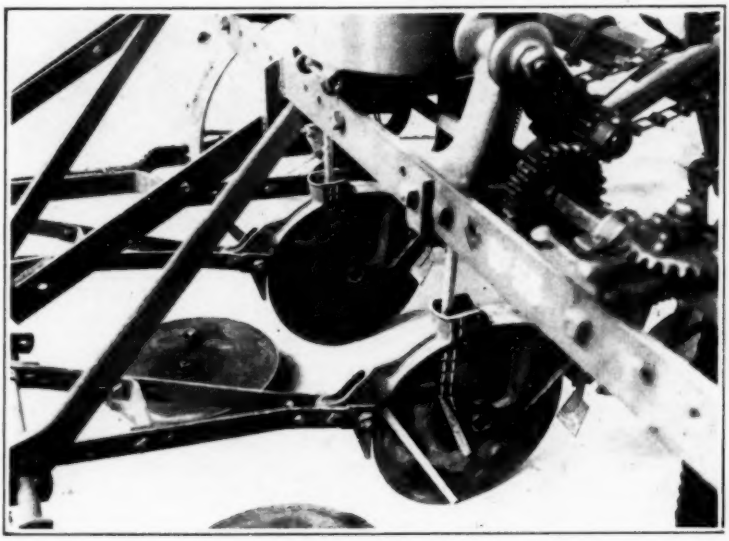

Figure 1.—John Deere No. 55 planter equipped with the small, smooth, straight seed tube in place of the regular, flexible tube on the far opener shown. The nearer opener is equipped with the long, small, smooth, slightly curved tube used in the tests. The dotted lines show the positions of the tubes inside the castings. The nearer opener is also equipped with the scraper bar between the disks which was used for treatment number 18 only.

ent seed as indicated. Briefly the planters are as follows: On the John Deere No. 55 planter the sloppiness had been taken out of the shaft bearings and drives and the opener units had been moved back about 2 inches to place the seed opening in the opener casting directly under the point of seed drop at the seed plate. The opener was the usual double disk opener and the press wheels were the regular type with a slight bevel to the rims, giving comparatively small concavity to the pair of wheels. Seed tubes differed as indicated. The small, straight tubes were of airplane tubing of 5/8 inch O. D. by 9/16 inch I. D. They were flared at the top just under the seed plates to insure all seed dropping into the tubes, and with the openers down in working position the tubes extended just into the disk opener castings so that the lower end of the tubes were slightly below the top edge of the opener disks. Seed dropped straight down these tubes actually dropped into the V between the lower edges of the opener disks and the disks had to turn to lay out the seed in the bottom of the furrow. The long, small curved tube used in this planter was of the same material as the short straight tube but extended about 8 inches lower. It curved back somewhat under the center of the opener disks at its

Table 1.—Summary of data from planter distribution study. Planted 5/3-4/45. Counts 6/2-8/45. (All tests at 2½ m.p.h. except as noted.)

	Planter and equipment	Seedsize, 64ths	Sprouts per viable seed	Percentage of potential germination*	No. of counts	Percent singles**	Largest gap, Inches
1	JD55 Small, smooth, straight tubes	7-10	1.56	37.5	48	67.72	23.33
2	JD55 Regular, flexible tubes	7-10	1.56	35.5	48	51.56	27.28
3	JD55 Small, straight tubes 3.8 m.p.h.	7-10	1.56	36.2	16	58.36	21.10
4	JD55 Small, straight tubes 5.0 m.p.h.	7-10	1.56	15.9	16	53.92	30.24
5	JD55 Flexible tubes 3.8 m.p.h.	7-10	1.56	36.4	16	53.34	20.05
6	JD55 Flexible tubes 5.0 m.p.h.	7-10	1.56	19.0	16	41.93	25.56
7	JD55 Long, small curved tube	7-10	1.56	36.2	16	56.57	22.70
8	McCD Small, curved tube, 11/64" cell	7-10	1.56	26.0	48	50.41	23.47
9	McCD Regular, flex. tube, 11/64" cell	7-10	1.56	33.8	48	58.28	23.43
10	McCD Regular, flex. tube, 12/64" cell	7-10	1.56	28.9	16	48.12	21.91
11	McCD Small, curved tube, 12/64" cell	7-10	1.56	27.4	16	50.40	20.11
12	JD Experimental planter	7-10	1.56	48.6	48	57.36	23.80
13	Rassmann unit	7-10	1.56	60.4	16	54.83	22.04
14	Ford planter	7-10	1.56	.....	16	56.43	25.84
15	JD55 Small, smooth, straight tubes	7-9	1.49	35.8	48	58.74	24.75
16	JD55 Long, small, curved tubes	7-9	1.49	27.4	48	67.67	25.29
17	JD55 Regular, flexible tubes	7-9	1.49	26.2	48	60.39	23.07
18	JD55 Small, smooth tubes, scraper between disks	7-9	1.49	48.0	16	58.05	18.45
19	JD55 Small, straight tubes, old style round end cut-offs	7-9	1.49	38.6	16	61.11	20.52
20	McCD Regular flexible tubes	7-9	1.49	29.2	16	53.54	20.30
21	JD Experimental planter	7-9	1.49	42.8	16	63.42	19.70
22	Cobbley with G. W. seed	7-9	1.49	37.2	18	53.28	19.27
23	Cobbley with U. I. seed	7-9	1.19	36.1	18	70.46	16.22
24	JD55 Small, straight, tubes, U-I seed	7-9	1.19	25.2	16	76.65	28.24
25	JD55 Small, str. tubes, decort. seed	7-9	1.67	54.3	16	50.95	19.86
26	JD55 Small, str. tubes, decort. seed	9-11	1.99	56.8	16	51.40	23.67
27	JD55 Small, str. tubes, blue pellets	.....	1.21	32.2†	16	70.78	24.52
28	McCD Flexible tubes, screened whole seed	8-11	1.71	33.4	16	54.72	22.96
29	Mervine's single seed planter, whole seed	.....	1.99	31.4	16	41.31	24.75
	Difference for significance 95-percent level						
	Between treatments of 16 counts			12.7		11.46	7.08
	Between treatments of 16 and 48 counts			10.4		9.17	5.78
	Between treatments of 48 counts			7.4		6.44	4.08

*Field germination expressed as percent of potential germination based on seed laboratory germination test and seeding rate.

**Percent of seedlings as singles (single seedling in 1 inch) adjusted to 35.6 average percent of potential germination and to 23.4 average seedling stand.

†Percent of potential germination determined from laboratory germination of base seed before pelleting was 16.0 percent.

lower end so as to drop seed into the opened furrow directly rather than into the V between the disks. The flexible tubes were those regularly supplied with the planters in the past.

The McCormick-Deering planter was the standard No. 40 beet planter with double disk openers. The small, curved tube used with this planter was like that on the John Deere No. 55 as it extended to

the bottom of the opener disks. However, it had a slight bend forward and a lower bend backward to get it down through the opener casting. Seed dropped from it in the opened furrow rather than in the V between the disks.

Plantings shown in lines 12 and 21 were with a John Deere No. 66 experimental, power lift, six-row planter with double disk openers and low seed hoppers mounted directly on the openers. The drives to the seed hoppers were through a front cross shaft, and bevel gears and fore-and-aft shafts. Press wheels on both this planter and on the McCormick-Deering were of the deep concavity type.

Seed plates on all three of these planters were ⅛-inch thick and had seed cells drilled 1/64 inch larger than the largest size of seed used, except for plantings 10 and 11 which had cells 2/64 inch larger than the largest size of seed.

The Rassman planter was a regular Rassmann unit built last year. The Ford planter was an experimental machine under development by Ford-Ferguson. It mounts directly on the rear of a Ford tractor and has horizontal seed plates driven by V-belts from press wheels of about 18 to 20 inches diameter. The openers are combination shovel furrowers and small runners. The Cobbley planter was this year's new Cobbley units mounted directly on John Deere No. 55 double disk openers. The seed tubes curved back slightly between the opener disks just enough to clear the disks and drop the seed in the opened furrow rather than in the V between the disks. Planting 29 was with a unit of Mervine's pick-up cup, single seed planter built several years ago.

Figure 2.—Ford-Ferguson experimental single-seed sugar beet planter under development in 1945.

The table shows seed used, sprouts per viable segment of the seed as determined from seed laboratory germinations, the number of 100 inch counts per planting, and the percent singles. The other two columns will be referred to later. Differences required for significance are shown at the bottoms of the columns.

In summarizing the results of this planting a number of the tabulated results have been combined. In comparing seed tubes, for example, the plantings with 7 to 9 and 7 to 10 seed have been combined. These combined results follow:

Seed tube comparisons	Percent singles
JD No. 55; long, smooth, curved seed tubes	64.9
smooth, straight seed tubes	63.2
regular flexible seed tubes	56.0
Difference for significance (95-percent)	4.6
McC-Drg No. 40; long, smooth, curved tubes	57.2
regular flexible tubes	55.7
Difference for significance	5.6
Planter speed:	
JD No. 55; straight and flexible tubes; 2.5 m.p.h.	59.6
3.8 m.p.h.	55.9
5.0 m.p.h.	47.9
Difference for significance	6.5

The percent singles decreases 2.9 percent for each mile per hour increase of planter speed.

Seed plate cell size:	
McC-Drg No. 40; plates with 11/64" cells and 7-10 seed	58.9
plates with 12/64" cells and 7-10 seed	49.3
Difference for significance	6.5
Planters—	
With both 7 to 9 and 7 to 10/64" seed	
JD No. 55; long, smooth curved seed tubes	64.9
JD No. 55; regular flexible tubes	56.0
McC-D No. 40; regular flexible tubes	57.1
J.D. experimental, low-hoppered drill	58.9
Difference for significance	5.6
With 7 to 10 seed	
J.D. No. 55; smooth, straight seed tubes	67.7
Rassman planter	54.8
Ford planter	56.4
Difference for significance	9.2
With 7 to 9 seed of two sprout counts	
JD No. 55; small, straight seed tubes	67.7
Cobbley	61.9
Difference for significance	7.9

Seed Size and Sprout Count

An analysis of all of the data where any one planter was tested with seed of two or more sprout counts per viable segment showed that on the average the percent singles decreased 3.0 percent for each increase of .1 in number of sprouts per viable segment.

Some of these results merely substantiate previous results but do give data which definitely show differences to be significant. The results with different planter speeds and with different seed sprout count make it possible to compare planters where different seed or speeds are used. It is rather significant that an increase in seed sprout count of .2 as from 1.2 to 1.4 sprouts per viable segment decreases the percent singles by 6.0 percent, which is nearly as much as the significant increase in percent singles obtained by replacing the flexible seed tubes of a John Deere No. 55 planter with the small straight seed tubes.

It has been suggested that the average size of the largest gap between seedlings in rows planted with different planters be used as a measure of the seedling distribution of the planter. Observations of the largest gap of each seedling stand count made in this study were made and the averages for each planter were adjusted to the average seedling stand. These average largest gap data are shown in the last column of the table and are directly comparable. There are some differences which roughly correspond to differences in percent singles, but in general the differences are not at all significant. The average largest gap for all the planters might be used as a measure of the germination condition of the field, but the percent of field emergence used later in this report seems to be a much better measure of the germination condition of a seed bed.

A study of the results of this planting and of our planting experience this spring leads to the following recommendations for planter design to improve seedling distribution characteristics:

1. Use small diameter, straight (or as nearly straight as possible) seed tubes dropping the seed in the bottom of the opened furrow and not into the V between opener disks.
   a. Tubes as small as 9/16 inch inside diameter are satisfactory. Smaller seed tubes with the seed properly guided into the tubes probably are satisfactory but we have no evidence on this.
   b. Seed tubes do not need to be a polished material inside like chrome plate, but care should be taken to determine that small seed tubes are free from spider webs, bugs or other obstructions each time planting is begun.
   c. Seed tubes should be as long as possible, preferably about down to the bottom of the opener disks in lifted position.

d. Have as near a fool proof and streamlined a transition of seed from plate to upper end of seed tubes as possible.

2. Use seed plates with round hole cells beveled up from the bottom with a 10° to 15° included angle reamed.

a. Have cells 1/64 inch larger than the largest size of seed in the range being planted; that is, 11/64 inch cells for 7 to 10 seed and 10/64 inch cells for 7 to 9 seed.

b. Use plates of a thickness not over ⅛ inch for 7 to 9 or 7 to 10 segmented seed.

c. Use plates and false plates with machined surfaces to give true surfaces and a minimum of grinding of seed.

3. Keep planter speed down to not over 2½ miles per hour.

4. Take out all play or back lash in planter drives to the seed plates.

5. Clamp seed hoppers down firmly and be sure the clamping arrangement pulls the hopper down squarely and that the plates run without binding after the hopper is clamped down.

6. Hopper height—No data which we have obtained or seen indicates that a planter with seed hoppers set directly on the disck opener castings to reduce the seep drop by a few inches gives any better distribution than one with the hoppers mounted directly on the planter frame as they normally are on the John Deere No. 55 planter if suitable small diameter seed tubes are used. Furthermore, the drives to the lower hoppers floating up and down are more elaborate and are likely to provide more allowance for back lash. I would therefore recommend continuing to mount the seed hoppers on the planter frame. Sales pressure may make it desirable to use the hopper mounting on the opener, however.

Study of Germination Characteristics of Planters

The second type of beet planter investigations was that of planter characteristics which affect field germination. Early, mid-season, and late-season plantings were used because weather is generally such a major factor in controlling field germination conditions. The first was planted on April 11 and 12 and soil moisture conditions were apparently ideal for normal planting. The soil had just dried out nicely to plant following a snow of about 12 inches. This planting was followed by another 12-inch snow and other lighter snows and rains so that we could not get into the field again until April 30. Moisture was therefore ample but the temperature was chilly and germination was very slow.

The second was put in on May 12 and 13 on a seed bed which

Figure 3.—Putting in planter plots with John Deere No. 55 sugar beet planter equipped with special planting equipment—two left openers with furrowers behind disk opener; right center is regular opener; right opener with V-rim press wheels.

had good moisture up to about an inch and a half from the surface. This seed bed had been worked up with a duck foot and spike tooth harrow to dry it out and give a seed bed with the surface on the dry side. However, rains followed which brought the moisture up to an optimum for germination and in that way did not give the dry planting we desired. The third was put in on June 29 and 30, which was the earliest that our seed bed could be put in a condition where it was definitely on the dry side and we were sure germination would be low with standard planting. There were some light showers on this planting but none ever wet down to the seed and the results were very different with different equipment.

On these germination studies we were concerned only with the percentage of the possible sprouts which actually came up. Germination counts therefore consisted of a count of the number of seedlings per 100 inches. Seeding rates were carefully determined and the potential number of sprouts for each planting was determined from the sprouts per hundred segments obtained in seed laboratory tests, the seed segments per pound, and the seeding rate. Results for each type of planting equipment are shown in tables 2, 3, and 4 for the three sets of plots as the field germination expressed in percentage of potential germination. The average field germination in Colorado expressed in this manner will usually range from 30 to 50 percent of potential germination.

The equipment used for the three sets of plots was much the same. On the first planting, treatment A was with the John Deere No. 55 used in the distribution study previously described, and the small,

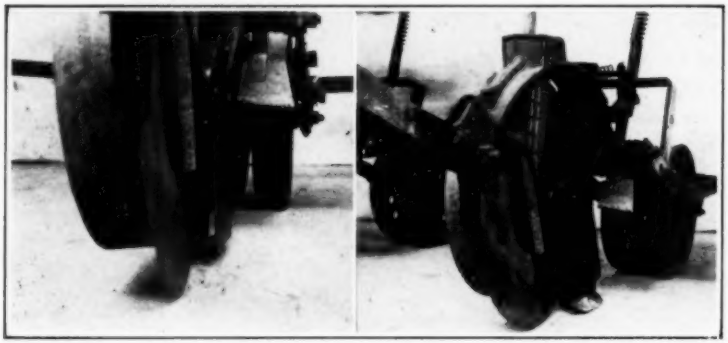

Figure 4.—Disk furrow openers with left disk removed to show small, moist soil, seed covers between disks. On the left is a single side coverer and on the right a double coverer. These coverers were designed to bring in a small amount of moist soil from the bottom of the furrow and cover the seed with it before dry soil fell in, but the devices did not improve germination significantly.

straight seed tubes were used. Depth was controlled in the usual manner with depth bands set in 1½ inches from the edges of opener disks, giving the actual planting depth of approximately 1¼ inches. On B the planting depth was controlled with the press wheels and was supposed to have been the same as A, but actually was deeper. Plantings C and D were with small, seed coverers which were developed to work between the opener disks and bring in a small amount of moist soil over the seed from the bottom of the opened furrow before dry surface soil fell in on the seed. These coverers were made single to bring in soil from only one side and double to bring soil from both sides. A special double set of V-rim press wheels were used for E in an attempt to obtain better covering and firming of the soil around the seed.

A set of furrowers was made up patterned after those developed by Great Western at Windsor, Colo., to use behind the opener disks. Depth bands were used on the opener disks to give about a 2½ inch depth of planting (bands set 2¾inches from disk edges), and the furrowers behind the disk openers were set to remove about 1¼ inches of soil and leave about 1¼ inches of soil over the seed. This produced a furrow type planting which was used for F and with the small seed coverers for G and H.

A small stream of water at the rate of about 150 gallons per acre was applied down the seed opener fertilizer spout for I. A similar stream of water was used for K except that it was applied just behind the single small seed coverer. In both cases the press wheels filled the opened furrow, leaving no evidence of the application of water on the seed.

Table 2.—Summary of results, first planter equipment germination study; 7-10 segmented, G. W. No. 92, seed treated with 4 ounces New Improved Ceresan and 12 ounces fume phosphate per 100, pounds seed; planted 4/11 and 12/45 at approximately 4 pounds per acre.

Tmt.	No. of counts	Planter and equipment	Field germination (percent of potential)
A	42	J.D. No. 55; regular with depth bands set to give 1½-inch depth	46.3
B	24	J.D. No. 55; depth controlled with presswheels	27.1
C	20	J.D. No. 55; small, double seed covers between disks and otherwise same as A	37.6
D	20	J.D. No. 55; small, single seed cover, otherwise same as A	38.3
E	24	J.D. No. 55; with double set of V-rim press wheels	45.4
F	24	J.D. No. 55; Windsor furrowers behind opener	38.5
G	20	J.D. No. 55; Windsor furrowers behind opener and small single seed coverer	43.8
H	19	J.D. No. 55; furrowers behind with small, double seed coverer	35.2
I	24	J.D. No. 55; regular opener with water on seed	43.6
J	24	J.D. No. 55; furrowing shovels ahead of opener	9.6
K	24	J.D. No. 55; with water following single, small seed coverer	43.5
L	20	J.D. No. 55; furrower ahead and small, double seed coverer	23.2
M	20	J.D. No. 55; furrower ahead and small, single seed coverer	23.7
N	20	J.D. No. 55; ridging disks following presswhee's and double seed coverers	16.8
O	20	J.D. No. 55; ridging disks following presswheels	10.5
P	24	McC-Drg No. 40; ridging disks following presswheels	16.9
Q	24	McC-Drg No. 40; regular with depth bands set for 1¼" depth	54.9
		Difference require for significance (95-percent level)	6.8

Furrowing shovels ahead of the disk openers which acted much like the clod pushers often used in California were used for planting J. The shovels were set to furrow about 1¼ to 1½ inches deep, and nomal depth planting was put in in the opened furrow. These same furrowers ahead of the openers were used for L and M with the small seed coverers described above. These furrowers as well as those used for F, G, and H are used to get the seed down into moisture when the surface soil is dry. They were used on the early plantings to see if they would be objectionable where there might be excess moisture either at planting time or immediately afterwards.

Pairs of small Plant Jr. ridging disks of 7-inch diameter were used behind the press wheels for plantings N, O, and P. The ridge which was about 1½ inches high was supposed to hold the moisture for germination and then be removed before the sprouts got up into the ridge. It developed that these ridges had to be removed by the fifth day after planting when germination conditions were favorable so that the ridges could be safely removed without damaging the sprouts.

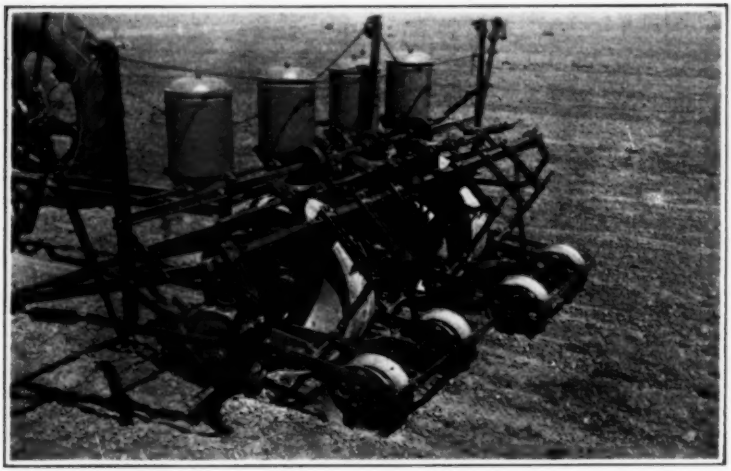

Figure 5.—Putting in planter plots with McCormick-Deering No. 40 sugar beet planted equipped with furrowing disks on the front of the two left disk openers and with furrowers behind the openers on the two right openers.

Plantings P and Q were put in with the McCormick-Deering No. 40 planter with the regular deep concavity press wheels. Planting Q was with the planter operating normally and with depth bands set in 1¼ inches from the edges of the disks. The press wheels used on the John Deere No. 55 planter were of the flat-beveled-rim type giving only slight concavity to the pair.

The lettering of treatments is different for the second set of germination study plots but the only differences in equipment used are as follows: For planting X the regular John Deere press wheels used in the furrow planting were replaced with one pair of the V-rim press wheels used for E. Sets of furrowing disks to act as clod pushers or furrowers ahead of the seed furrow openers were used for planting R. Plantings T and V were put in with decorticated seed prepared for us from our base seed by the California Experiment Station at Davis. In one case the seed was planted dry and in the other the seed was presoaked and surface dried for planting.

The results for the first and second set of germination study plots will be discussed together since they were more or less similar because of similar moisture conditions. In general the standard or check plantings were the best and most of the other special plantings had a more or less detrimental effect on germination. On the first

Table 3.—Summary of results, second planter equipment germination study. Planted 5/11 and 12/45 with 7-10 G. W. No. 92 segmented seed treated with 4 ounces New Improved Ceresan and 16 ounces fume phosphate per 100 pounds of seed. Planted at aproximately 4 pounds per acre.

Tmt.	No. of counts	Planter and equipment	Field germination (percent of potential)
A	40	J.D. No. 55; regular with depth bands set for 1½-inch depth	66.5
B	16	J.D. No. 55; depth controlled with press wheels	39.2
C	16	J.D. No. 55; small, double seed coverers	73.5
D	16	J.D. No. 55; small, single seed coverer	66.9
E	16	J.D. No. 55; with double set of V-rim press wheels	67.6
F	16	J.D. No. 55; Windsor type of furrowers behind opener	35.2
X	16	J.D. No. 55; Windsor type of furrowers behind opener and one pair of V-rim press wheels	47.1
V	16	J.D. No. 55; furrowers behind openers with depth controlled by press wheels	44.7
G	16	J.D. No. 55; Windsor type furrowers behind openers and single small coverer	37.0
H	16	J.D. No. 55; Windsor type furrowers behind openers and double small coverers	43.0
I	16	J.D. No. 55; with water on seed	57.8
J	16	J.D. No. 55; with furrowers ahead of openers	25.4
K	16	J.D. No. 55; water following single small seed coverer	62.0
L	16	J.D. No. 55; furrows ahead and small double coverers	21.0
M	16	J.D. No. 55; furrowers ahead and small single coverer	20.6
W	16	J.D. No. 55; furrowers ahead set for shallower planting	49.5
NO	16	J.D. No. 55; small Planet Jr. ridgers following press wheels	63.3
Q	16	McC-Drg; regular with depth bands set for 1¼-inch depth	67.0
P	16	McC-Drg; small Planet Jr. ridgers following press wheels	66.0
R	16	McC-Drg; small furrowing disks ahead of opener disks	22.3
S	16	McC-Drg; furrowers behind openers	32.0
T	16	McC-Drg; 7-9 wet decorticated seed, 1¼-inch depth bands	31.2
U	16	McC-Drg; 7-9 dry decorticated seed, 1¼-inch depth bands	44.5
		Difference required for significance, treatments of 16 counts	9.3
		between treatments of 16 and 40 counts	7.8

planting the differences between Q, A, and B are, I believe, attributable to depth of planting. The shallower planting Q did significantly better and the deeper planting B was significantly poorer than A, probably because of the cold, slow germination weather.

The furrow plantings of both sets of plots were very significantly poorer than the regular planting. This was largely the result of going in poorly and poor covering of the seed. None of these furrow plantings went in well or covered well where the surface soil was moist and the subsurface soil was moist and firm. The planting with furrowers ahead of the openers went in particularly poorly because ribbons of moist soil came up around the outer edges of the opener disks and in dropping off left a rough surface and not enough pressure could be put on the press wheels to cover the seed. It seemed that this type of planting should be used only when necessary to get the seed down into moisture. Then, too, these rows were harder to thin

Table 4.—Summary of results, third planter equipment germination study. Planted 6/29 and 30/45 at 4 pounds per acre with 7-10 segmented G. W. No. 92 seed treated with 4 ounces New Improved Ceresan and 12 ounces fume phosphate per 100 pounds of seed except as noted.

Pltg.	Planter and equipment	Field germination (percent of potential)
B & I	J.D. No. 55; regular opener with bands at 1½-inch depth	6.6
D	J.D. No. 55; small double seed coverers between disks	8.1
E	J.D. No. 55; small single seed coverer between disks	9.4
C	J.D. No. 55; double set of V-rim press wheels	11.2
H	J.D. No. 55; regular opener with bands at 2-inch depth	31.1
J	J.D. No. 55; regular with bands at 1½-inch depth and IHC press wheels	7.6
A	J.D. No. 55; Windsor type furrowers behind openers, bands at 2¾-inch depth	47.6
N	J.D. No. 55; furrowing shovels or clod pushers ahead of openers	47.6
F	J.D. No. 55; stream of water following small single seed coverer	9.9
G	J.D. No. 55; stream of water following directly on seed	16.5
K_1	J.D. No. 55; large ridgers (2½-inch ridges); ridges removed	8.4
K_2	J.D. No. 55; large ridgers (2½-inch ridges); ridges left	1.4
L_1	J.D. No. 55; small ridgers (1½-inch ridges); ridges removed	4.7
L_2	J.D. No. 55; small ridgers (1½-inch ridges); ridges left	2.2
M	J.D. No. 55; regular openers, bands at 1½-inch, 8-11 whole seed in 12/64-inch cells at 3.61 pounds per acre	2.5
O	J.D. No. 55; regular opener, 7-9 dry decorticated seed	2.0
P	J.D. No. 55; regular opener, 7-9 wet decorticated seed	4.7
Q	McC-D No. 40; furrowing shovels behind openers, bands at 2¾ inches	29.5
R	McC-D No. 40; furrowing disks ahead of openers	22.2
S	McC-D No. 40; regular openers with bands at 1¼-inch depth	6.3
T_1	McC-D No. 40; small ridgers (1½-inch ridges); ridges removed	2.0
T_2	McC-D No. 40; small ridgers (1½-inch ridges); ridges left	1.0
U & V	J.D. Experimental planter	7.6
W	J.D. low hoppered No. 55, bands at 2-inch depth	18.4
X	J.D. low hoppered No. 55, bands at 1½-inch depth	2.0
	Difference required for significance (95-percent)	4.9

than normally planted rows because it was hard to get the hoe down into the furrow.

On the first set of plots the ridged plantings could not be uncovered because the field was too wet to work for 18 days after planting and by then the sprouts were up into the ridges. These plantings were therefore very poor. On the second set of plots the ridges were removed in 5 days after planting and these plantings were practically identical in germination with the rows planted normally.

In general the small seed coverers did no good and sometimes reduced germination. The V-rim press wheels gave results about the same as regular planting except that when used in furrow planting as for X in the second set of plots, they produced better seed covering

Figure 6.—Equipment used for putting in the covered or ridged row, sugar beet plantings. The two left openers have the large ridging disks and the two right the smaller disks. Ridges must be removed by about the fourth day after planting before the sprouts get up into the ridges.

and increased germination. Water on the seed seemed to depress germination slightly on both sets of plots but not significantly so. For some reason the germination of both wet and dry decorticated seed on the second set of plots was significantly different and significantly below the regular plantings with segmented seed.

The seed bed on the third set of germination study plots was distinctly on the dry side as shown by the very low field germination of the regular plantings. Some new equipment or treatments were used on this set of plots which were not used on the first two sets. Planting H is similar to B and I which are regular except that for H the depth bands were set in 2 inches from the disk edges. Larger ridging disks were used for K_1 and K_2 than those previously used and used on this set of plots for L_1 and L_2, T_1 and T_2. These larger disks replaced the press wheels and made ridges 2½ inches high. They were adapted by Great Western at Windsor in an attempt to bring up moist soil over the planted row. The John Deere experimental low-hoppered drill was used for U and V, and a special low hoppered John Deere No. 55 drill built up at Windsor was used for W and X.

The only very good germination stands on this planting were obtained with the furrow planting. Both the furrowers ahead of the openers and behind were equally good and both plantings went in in nice shape. The planting with depth bands set for 2 inch depth

(actual planting depth approximately 1¾ inches) was very much better than that with bands set for 1½ inch depth (actual depth approximately 1¼ inches), showing that the shallower planting hardly got into moisture. Water directly on the seed increased the germination percentage significantly and the V-rim press wheels improved germination but not significantly so. The furrow plantings and the 2 inch depth of planting were the only ones which would produce a satisfactory thinned stand in this set of plots.

The percentage of field emergence was worked out for the seedling distribution study plots and is shown in column three of table 1. It contains some interesting results. The John Deere No. 66 experimental planter gave significantly better germination. This might have been because the planter was heavier and more pressure could be put on the press wheels. The seed bed was on the firm side and considerable press wheel pressure was needed to cover the seed. This was shown by the fact that not enough pressure could be put on the Mcormick-Deering planter deep-concavity press wheels to cover the seed well and the germinations with this planter were usually significantly lower.

Another thing of particular interest was the high germination with the Rassmann unit. This unit used a double disk opener with a small secondary runner opener in the bottom of the opened furrow. Planting 18 with a small scraper between the disks to flatten off the bottom of the furrow opened by the disk opener was also significantly better than regular planting. Apparently something should be done to the bottom of the opened furrow to smooth or flatten it to improve field germination.

The germination of the pelleted seed was very low when based on the germination of the base seed used for pelleting. However, when field germination is based on seed laboratory germination tests the percentage field germination on this planting was not much lower than the regular plantings, though the number of seedlings was low. The germination of the decorticated seed was very significantly higher than for the segmented seed planting on this set of plots, which is a reversal of results from those in the second set of germination study plots. Wet and dry decorticated seed here were practically the same.

This matter of field emergence is now probably more important in its bearing on mechanized thinning than further improvements in seedling distribution. It is a problem to which we intend to give increased attention.

A study of the data obtained in the planter germination investigations and our experience this past spring prompts the following sug-

gestions, particularly for Colorado conditions, for improving the percentage of field emergence, though they are not listed in any order of importance:

1. Use more pressure on press wheels, particularly on firm seed beds. Care must be taken not to overdo this because the planter weight will be largely carried on the press wheels and slippage will be excessive.

2. Loosen up the surface of firm seed beds by surface harrowing prior to planting. This also is effective in control of early weeds which come in fields where planting is delayed by rains or snows.

3. Use deep concavity press wheels with considerable pressure for loose seed beds.

4. For firm seed beds use shallow concavity press wheels or set deep concavity press wheels close together and be sure the seed is well and firmly covered.

5. Level, scrape, or smooth out the bottom of the seed furrow before dropping seed. Considerable experimental work should be done to develop suitable equipment to do this.

6. Use shallower depths for early plantings when germination is slow and moisture may be excessive.

7. Use deeper plantings for later plantings when soil is likely to be dry and germination is rapid.

8. Use furrow planting only when necessary to get the seed into moisture. The furrow planting with furrowers behind the disk openers usually goes in better and the depth can be more accurately controlled than with furrowers ahead of the seed furrow openers.

9. Our plantings have not shown the ridged planting to be of any benefit. However, for late plantings or for irrigating up or in weedy conditions where removal of ridges would assist in weed control, the ridged planting probably would be desirable. It should be used only where one has assurance that the ridges can be removed in time to avoid damage to sprouting seedlings.

Sugar Beet Planter Tests In Imperial Valley, Calif., Fall, 1945

G. W. HOWARD[1]

Purposes of Imperial Valley tests (November 20-December 20, 1945) were to do some work along the following lines:

1. Standardize type of seed.
2. Test planters at different rates of seeding and different speeds.
3. Attempt to make mechanical recommendations based upon stands that developed.

Nine drills were tested:

1. John Deere No. 55.
   a. Long curved smooth tube.
   b. Short straight smooth tube.
2. John Deere low can—forerunner of Model No. 66 drill.
3. I. H. C. conversion to smooth tube from No. 40 with telescoped smooth tubes.
4. I. H. C. No. 46 low can drill.
5. Cobbley (Not the Plant-trol unit)
6. Rassmann
7. Aircraft Mechanics
8. Olson
9. Ford Ferguson

The following drills have been considered as commercial drills:
John Deere No. 55
I. H. C. No. 40
Cobbley
Rassmann

The balance should be considered as experimental drills.

We had planned to include the Case drill with their latest improved plates but were unable to do so because this equipment arrived in Brawley too late for any work to be done with it. We are, however,

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[1]Staff Engineer, Beet Sugar Development Foundation, Fort Collins, Colo.

carrying on experiments at the present time in cooperation with the U. S. Department of Agriculture and Colorado A & M College at Fort Collins. These late tests show that with use of a special machined filler plate and a cell plate built especially for segmented seed, the grinding of the Case planters is practically negligible.

Greased board tests were in general made at 2, 3, 4½, and 6 miles per hour and at seeding rates of as close to 2, 4, 6, 8, and 10 seeds per foot as practicable.

Three replicated samples of seed from 200 feet of row were taken off the test rack alternately between each 100 inches of greased board. These samples were sent to the laboratories for comparison with original seed samples to determine seed damage. One of these samples was sent to J. A. Bair of the Great Western Sugar Company at Fort Collins. The seed was actually counted after having been run over a 6/64 screen. This figure was used to determine cell fill in our various drill tests. The other two samples were sent to C. E. Cormany of Holly Sugar Corporation at Sheridan for replicated germination tests.

Field plantings were made one row at a time at 3 miles per hour only. In the drill comparisons three replicated plots of each test

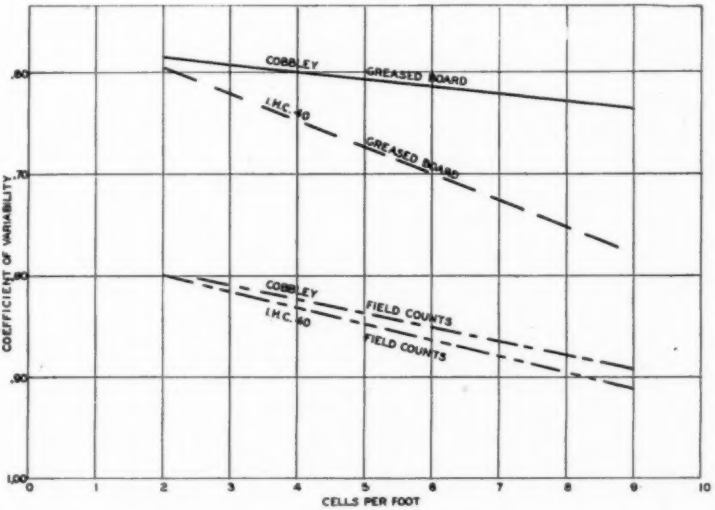


Figure 1.—Loss of pattern, greased board, 3 m.p.h., field.

were made. From each of these plots twenty 100-inch counts were made in the following manner; the first count started at 15 feet from the end of the plot and 5 feet was allowed between each 100-inch count. From these assembled data we are making the following calculations:

TOTAL BEET-CONTAINING INCHES

Single plants
Double plants
Three or more
Longest gap
Total plants in 100 inches

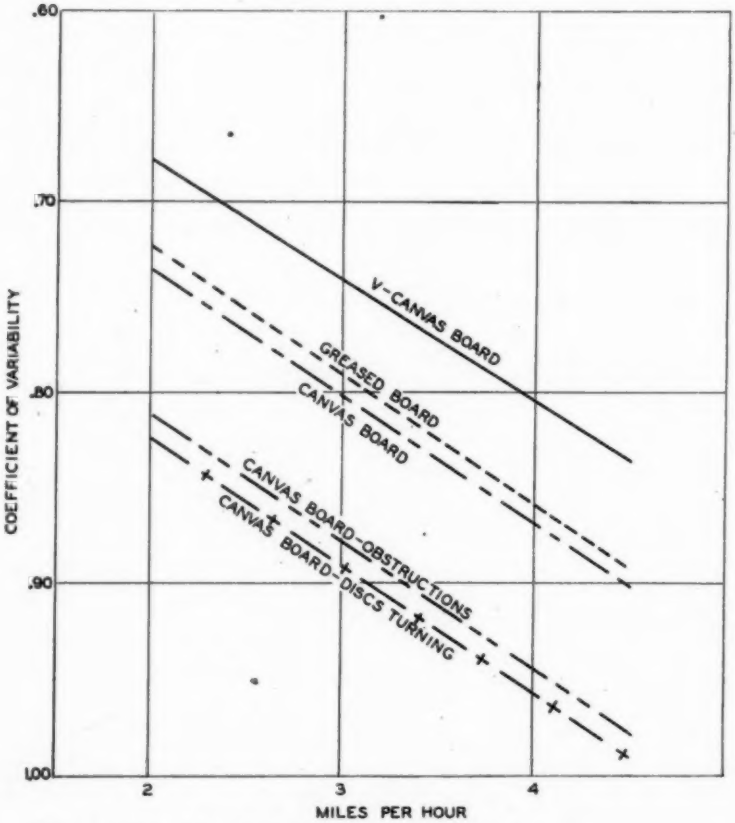


Figure 2.—Study of seed roll from forward drill motion.

We have also used these data to compare, in a limited way, the greased board data from the same drill. (Table 1).

We attempted to take as thorough and dependable data as possible and were unbiased in our operations. All those who worked on the Brawley tests had in mind that we were after drill and planting information in general and were not out to give any certain party a boost nor to bring discredit to any drill or organization.

Those who worked on the tests for the Beet Sugar Development Foundation, directly under P. B. Smith, were: S. W. McBirney, U. S. Department of Agriculture, A. J. Bigler, Utah-Idaho Sugar Company; Norman Lawlor, American Crystal Sugar Company; W. E. Walters, Great Western Sugar Company; E. P. Pattison, Holly Sugar Corporation; Chris Lohry, Great Western Sugar Company; and G. W. Howard, Beet Sugar Development Foundation.

We received fine cooperation from all implement people and especially from the following persons: R. C. Brown, agricultural

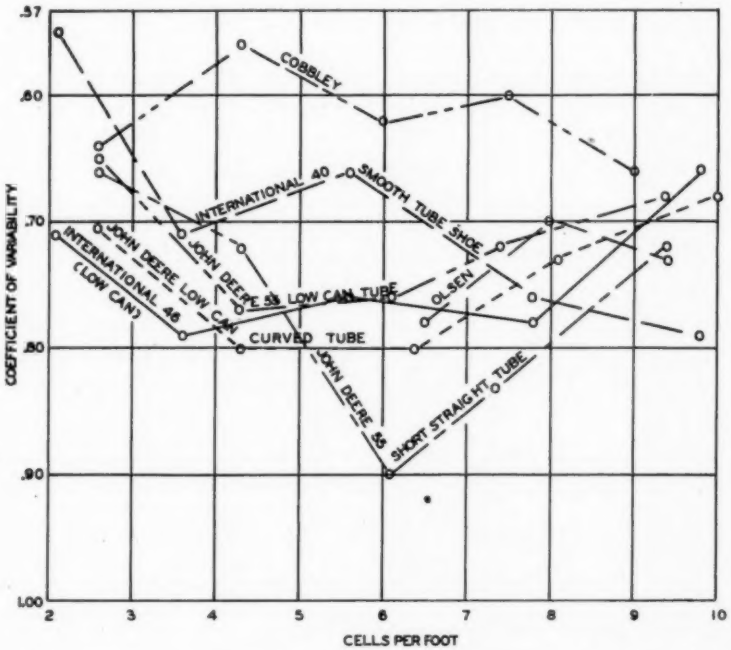


Figure 3.—Pattern comparisons, various drills, 3 m.p.h., greased board.

superintendent, Holly Sugar Corporation, Brawley, Calif.; Robert Barr, field man, Holly Sugar Corporation, El Centro, Calif.; H. V. Hansen, planter engineer, and George Cole of the Research staff, both of Ford-Ferguson Company; Hugo Rassmann, designer, of Diamond Iron Works; G. H. Kriegbaum, chief engineer, International Harvester Company; V. F. Bozeman, general manager, John Deere Wagon Works; Proctor Nichols, president, Aircraft Mechanics; E. F. Kratz, sales manager, J. I. Case Company; Harold J. Agee, manager, Olson Manufacturing Company; Roy Bainer, agricultural engineer, University of California; C. E. Cormany, research manager, Holly Sugar Corporatino; A. A. Schupp and Phelps Vogelsang, of Farmers and Manufacturers Beet Sugar Association; J. A. Bair, chief chemist, Great Western Sugar Company; Ralph Partridge, factory manager, Great Western Sugar Company, Fort Collins, Colo.; E. M. Mervine, agricultural engineer, Colorado A & M College; John Edmiston, factory manager, Great Western Sugar Company, Windsor, Colo.; Roy Marsh, fieldman, Great Western Sugar Company, Windsor, Colo.

Judging from Brawley data several points seem evident:

(1) There is no perfect beet drill to date.

(2) The greased board and electronics tester are questionable methods of testing overall drills. We did not attempt to test metering devices alone, but to test each drill as it would actually go into the field.

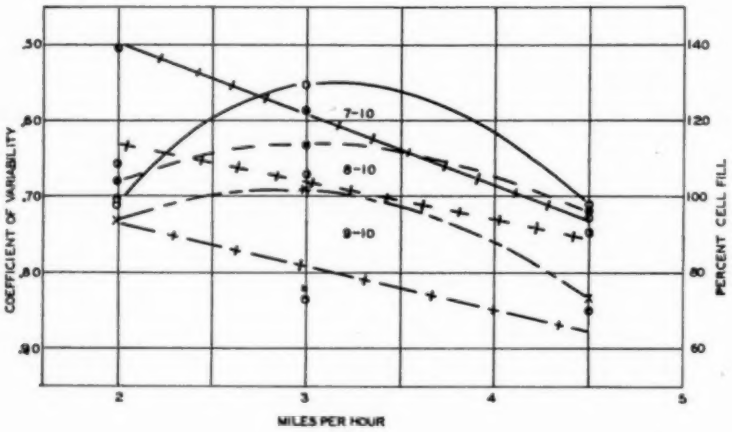


Figure 4.—Pattern and cell fill, Rassman, various seed sizes, 11/64 plates.

(3) A good formula for evaluating both pattern on the greased board and field germination stands should be developed. We have used in our tests Roland Cannon's "Coefficient of Variability" procedure because it evaluates pattern by a relatively short method. By choosing this method, we do not wish to discredit any other evaluation procedure. It does not, however, consider cell fill nor grinding of seed. These two variables will be hard to include in a pattern evaluating method.

(4) We are convinced that it is necessary to do considerable more work in getting the perfect beet seed which might include seed processing as well as seed breeding. Table 1 shows pattern comparisons with seed used in the Imperial Valley tests.

(5) Improvements in emergence should be studied.

A considerable loss of pattern occurs between the greased board and the field. (Figure 1). Results from two common drills have been compared to show a difference of 15 to 25 percent loss. Some of this loss is a result of improper germination and some can be attributed to difference in cell fill, but a good portion, we believe, is due to the difference in forward roll of the beet seed after it leaves the moving drill. No drills on the market today take into account the forward motion of the drill in distributing the seed. This fact cannot be overlooked in explaining the difference between greased board results and actual field plantings. To try to pin this roll value down we have just completed some tests at Windsor. (Figure 2). These results did not turn out exactly as expected but are nevertheless somewhat revealing.

The best value in coefficient of variability was obtained by stitching a 12 inch piece of 8 ounce dam canvas in the center and bending the two edges outward, nailing them on the 6 inch board. This "V"

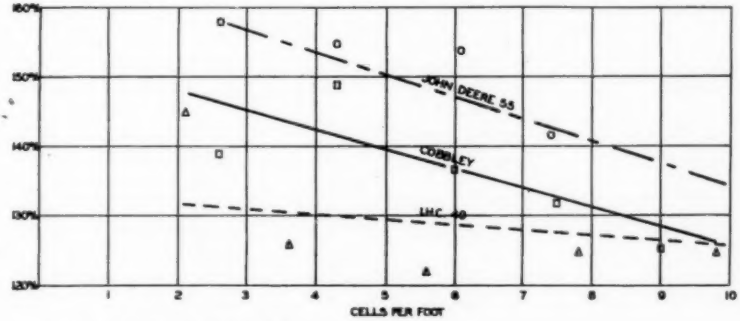


Figure 5.—Cellfill at 3 m.p.h.

Table 1.—Pattern comparisons greased board, Imperial Valley planter tests. Miles per hour Seeding rate 2.1 cells per foot.

	2 m.p.h.		3 m.p.h.		4.5 m.p.h.		6 m.p.h.	
Planter	Rate	Coef. of variability	Rate Seeds per foot	Coef. of variability	Rate Seeds per foot	Coef. of variability	Rate Seeds per foot	Coef. of variability
Cobbley			2.6	.64	2.6	.66	2.6	.92
Cobbley			4.35	.56	4.3	.58	4.3	.72
Cobbley			6.00	.62	6.0	.63	6.0	.72
Cobbley			7.5	.60	7.5	.68	7.4	.66
Cobbley			9.0	.66	9.0	.70	9.0	.79
I.H.C. No. 40—shoe	2.1	.61	2.1	.55	2.1	.57		
I.H.C. No. 40—shoe	3.6	.57	3.6	.71	3.6	.68		
I.H.C. No. 40—shoe	5.6	.64	5.6	.66	5.6	.92		
I.H.C. No. 40—shoe	7.8	.70	7.8	.76	7.8	.87		
I.H.C. No. 40—shoe	9.8	.77	9.8	.78	9.8	.78		
J.D. low can, curved tube			2.6	.71	2.6	.69	2.56	.79
J.D. low can, curved tube			4.3	.80	4.29	.78	4.29	.99
J.D. low can, curved tube			6.42	.80	6.42	.87	6.42	.86
J.D. low can, curved tube			8.1	.73	8.1	.87	8.1	.83
J.D. low can, curved tube			10.0	.68	10.0	.85	10.0	.89
J.D. No. 55, McBirney tube			2.6	.66	2.6	.75	2.6	.77
J.D. No. 55, McBirney tube			4.3	.73	4.3	.81	4.3	.98
J.D. No. 55, McBirney tube			6.1	.90	6.1	.84	6.1	.88
J.D. No. 55, McBirney tube			7.4	.83	7.4	.87	7.4	.71
J.D. No. 55, McBirney tube			9.4	.72	9.4	.82	9.4	.90
I.H.C. No. 46 low can	2.1	.64	2.1	.71	2.1	.75		
I.H.C. No 46 low can	3.6	.74	3.6	.79	3.6	.83		
I.H.C. No. 46 low can	5.6	.74	5.6	.76	5.6	.74		
I.H.C. No. 46 low can	7.8	.71	7.8	.78	7.8	.70		
I.H.C. No. 46 low can	9.8	.74	9.8	.66	9.8	.90		
Olson	6.5	.75	6.5	.78	6.5	.65		
Olson	8.0	.69	8.0	.70	8.0	.78		
Olson	9.4	.70	9.4	.73	9.4	.74		
Rassmann 7/10	8.0	.71	8.1	.55	8.1	.71		
Rassmann 8/10	8.1	.68	8.1	.63	8.1	.72		
Rassmann 9/10	8.1	.73	8.1	.69	8.1	.83		
J.D. No. 55 low curved tube			2.6	.65	2.6	.67	2.6	.75
J.D. No. 55 low curved tube			4.3	.77	4.3	.74	4.3	.81
J.D. No. 55 low curved tube			6.1	.76	6.1	.84	6.1	.81
J.D. No. 55 low curved tube			9.4	.68	9.4	.85	9.4	.95
J.D. No. 55 low curved tube			7.4	.72	7.4	.81	7.4	.77
I.H.C. No. 40 spiral tube	2.1	.91	2.1	.81	2.1	.71		
Aircraft Mechanics	12.0	.79	12.0	.69	12.0	.81		

canvas immediately wedged the seed as it came out of the seed tube and apparently eliminated any roll or distortion whatsoever. Another canvas board was then tried which had a round bottom allowing the seed to roll. The coefficient of variability of this board and the greased board came out practically the same but about 8 percent worse than the "V" canvas, indicating that if the seed roll was

present it was all approximately equal when no obstructions were present. We then ran the latter board under two other conditions, first with interference particles spaced along the board and second, with the discs actually turning on the board. These two boards gave patterns almost identical but about 10 percent less favorable than the

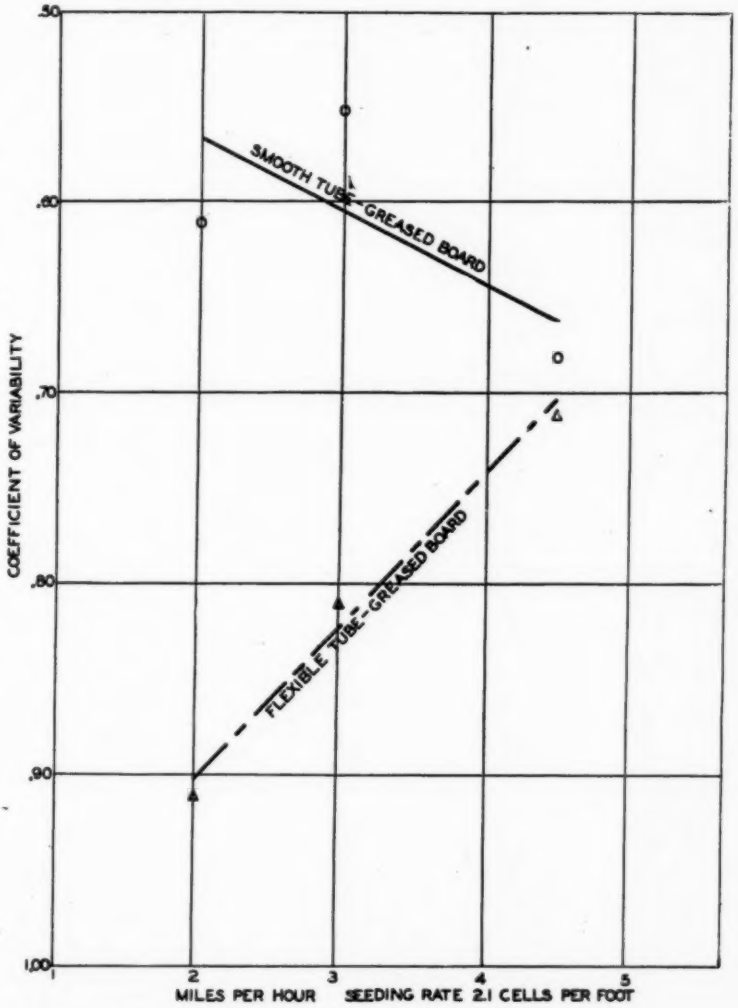


Figure 6.—Flexible tube—smooth tube comparisons, I. H. C. No. 40.

Table 2.—Comparison of various planters at 2 miles per hour (grease board test), Brawley, Calif., test.

Planter	Actual pounds of 7/9 seed used per acre*	Theoretical cells per foot row	Percent actual cell fill	Actual number of sprouts per 100 feet of row**	Total potential sprouts per 100 feet of row	Seed pieces larger than 6/64 remaining per 100 feet of row	Total sprouts per 100 feet of row after passing metering device	Sprouts lost per 100 feet of row		Total sprouts per 100 feet of row after passing metering device; as percentage of theoretical seeding
								No.	Percent	
I.H.C. No. 40	1.40	2.1	149	313	307	293	261	46	15	124
	2.32	3.6	145	522	512	484	421	91	18	117
	3.38	5.6	135	755	740	703	583	157	21	104
	5.18	7.8	148	1,156	1,133	1,065	831	302	27	107
	6.29	9.8	143	1,401	1,373	1,297	1,051	322	23	107
I.H.C. No. 46	1.76	2.1	187	392	384	369	339	45	12	161
	3.98	5.6	159	893	875	842	775	100	11	138
	4.83	7.8	138	1,075	1,054	1,012	911	143	14	117
	5.81	9.8	132	1,289	1,263	1,219	1,134	129	10	116
Olson	1.94	6.5	67	437	428	411	345	83	19	53
	2.95	8.0	82	654	641	617	543	98	15	68
	2.77	9.4	66	621	609	601	421	188	31	45
Rassmann 7/10		8.1	145	1,174	1,151	1,127	992			122
*** 8/10		8.1	113	917	899	889	747			92
9/10		8.1	101	815	799	804	852			105
Aircraft Mechanics	5.99	12.0	111	1,336		1,067	768			64

*Percent cell fill considered in computations.
**Based on average of three tests of 200 feet each.
***Only 11/64 plates available.

greased board and plain round bottom canvas board. These tests are preliminary but we believe they point towards a method of evaluating seed roll.

If we establish that the forward seed roll is harmful to field seed distribution we need a standard of measuring pattern to test overall drills. Our thinking has gone as far as to design a pilot experimental seed metering device which will induce backward rotor speed equal to the forward drill motion allowing seed to drop in a dead fall without forward or backward motion. We expect trouble with cell fill and knockout with this new design but we have taken steps to solve these problems. With this experimental model we plan to do some work in the canvas board and on the greased board. If our results are somewhat equal we believe we will have accomplished something important in the testing of the drill as it goes into the field.

In comparing pattern values (Figure 3) from the greased board we note that the Cobbley is higher than the other drills. A similarity of the John Deere long curved tube and the John Deere low can lines

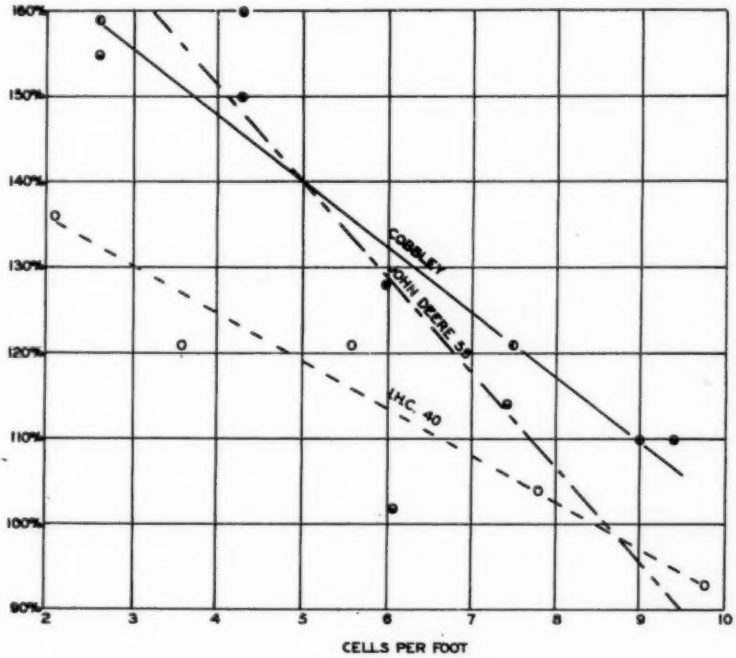


Table 3.—Comparison of various planters at 3 miles per hour (grease board and field tests), Brawley, Calif., test.

Planter	Actual pounds of 7/9 seed used per acre*	Theoretical cells per foot row	Percent actual cell fill	Actual number of seeds per 100 feet of row**	Total potential sprouts per 100 feet of row	Seed pieces larger than 6/64 remaining per 100 feet of row	Total sprouts per 100 feet of row after passing metering device	Sprouts lost per 100 feet of row		Total sprouts per 100 feet of row after passing metering device as percentage of theoretical seeding	Total plants emerging Per 100 feet of row in field***	Percent emergence in field	Percent of single beet containing inches
								No.	Percent				
I.H.C. No. 40	1.47	2.1	156	327	320	304	255	65	20	121	189	90	84
	2.19	3.6	137	494	484	455	382	102	21	106	324	90	80
	3.28	5.6	131	732	717	681	531	186	26	95	476	82	79
	4.69	7.8	134	1045	1024	975	780	244	24	100	616	76	74
	5.85	9.8	133	1305	1279	1222	831	448	35	85	727	72	68
I.H.C. No. 46	1.03	2.1	173	364	357	344	299	58	16	142	252	120	85
	2.67	3.6	167	600	588	561	482	106	18	134	385	107	80
	4.05	5.6	162	905	887	856	710	177	20	127	515	92	77
	4.59	7.8	131	1019	996	958	843	153	15	108	656	81	71
	5.02	9.8	114	1121	1099	1067	736	363	33	75	727	72	67
J. D. Low Can (curved tube)	2.28	2.56	190	487	477	460	386	91	19	151	302	116	85
	3.42	4.3	180	777	761	721	634	127	17	147	451	105	79
	4.12	6.4	142	908	890	856	685	205	23	107	640	100	73
	4.93	8.1	137	1111	1089	1054	780	309	28	96	779	95	68
	6.21	10.0	138	1377	1349	1305	940	409	30	94	809	87	65
J. D. No. 55 (long curved tube)	2.00	2.6	167	434	425	405	369	56	13	142	318	138	86
	3.14	4.3	165	708	694	668	588	106	15	137	411	105	80
	4.40	6.1	163	992	972	939	808	164	17	132	573	97	73
	4.95	7.4	150	1168	1086	1048	838	248	23	113	670	90	72
	5.75	9.4	137	1285	1259	1219	890	369	29	95	864	92	65

Table 3.—Continued.

Cobbley	1.88	2.6	157	408	400	362	297	103	26	114	193	88	84
	3.15	4.3	166	713	699	642	514	185	26	120	273	76	84
	4.10	6.0	152	914	896	818	679	217	24	113	462	74	79
	5.03	7.5	148	1107	1085	994	815	270	25	114	538	70	76
	5.64	9.0	141	1272	1247	1153	842	405	32	94	675	72	73
Olson	1.86	6.5	64	419	411	364	306	105	26	47	175	27	88
	2.12	8.0	59	471	462	406	357	105	23	45	185	23	86
	1.72	9.4	41	387	379	353	247	132	35	26	131	14	89
Rassmann 7/10		8.1	127	1028	1007	997	808			100	616	82	69
**** 8/10		8.1	108	876	358	856	907			112			
9/10		8.1	75	608	596	597	669			83			
Aircraft Mechanic	5.89	12.0	109	1305		1060	670			56	312	26	82

*Percent cell fill considered in computation.
**Based on average of three tests of 200 feet each.
***Based on average of 60 field counts of 100 inches each.
****Only 11/64 plates available.

Table 4.—Comparison of various planters at 4½ miles per hour (grease board test), Brawley, Calif., test.

Planter	Actual pounds of 7/0 seed used per acre*	Theoretical cells per foot row	Percent actual cell fill	Actual number of sprouts per 100 feet of row**	Total potential sprouts per 100 feet of row	Seed pieces larger than 6/64 remaining per 100 feet of row	Total sprouts per 100 feet of row after passing metering device	Sprouts lost per 100 feet of row		Total sprouts per 100 feet of row after passing metering device; as percentage of theoretical seeding
								No.	Percent	
I.H.C. No. 40	1.35	2.1	144	303	297	285	239	58	20	114
	2.10	3.6	131	471	462	437	363	99	21	101
	3.23	5.6	129	725	711	677	528	183	25	94
	3.92	7.8	112	873	856	815	644	212	25	83
	4.36	9.8	99	975	956	913	630	326	34	65
I.H.C. No. 46	1.65	2.1	176	369	362	352	268	94	26	128
	2.53	3.6	158	568	557	534	427	130	23	119
	3.55	5.6	142	793	777	751	571	206	27	102
	3.92	7.8	112	873	856	828	629	227	27	81
	3.70	9.8	84	828	811	810	616	195	24	63
J. D. Low Can (curved tube)	2.11	2.6	176	457	448	432	346	102	23	133
	3.17	4.3	167	720	706	684	575	131	19	134
	4.06	6.4	140	803	875	843	666	209	24	104
	4.75	8.1	132	1,069	1,048	1,019	836	212	20	103
	4.86	10.0	108	1,075	1,054	1,029	772	282	27	77
J. D. No. 55 (long curved tube)	1.94	2.6	162	421	413	403	363	50	12	140
	3.17	4.3	167	718	704	687	598	106	15	139
	2.86	6.1	106	649	636	625	506	130	20	83
	4.03	7.4	122	901	883	868	720	163	18	97
	4.75	9.4	113	1,065	1,044	1,031	814	230	22	87

Table 4.—Continued.

Cobbley	2.09	2.6	174	452	443	414	339	104	23	130
	2.93	4.3	154	663	650	602	506	144	22	118
	3.92	6.0	145	872	855	769	646	209	24	108
	4.66	7.5	137	1,025	1,005	912	812	193	19	108
	4.96	9.0	124	1,120	1,098	995	816	282	26	91
Olson	2.61	6.5	90	582	570	442	371	199	35	57
	2.45	8.0	68	545	534	391	344	190	36	43
	1.55	9.4	37	350	343	247	173	170	50	18
Rassmann 7/10		8.1	101	817	801	771	663			82
*** 8/10		8.1	101	770	755	749	697			86
9/10		8.1	70	569	558	558	547			68
Aircraft Mechanic	3.67	12.	68	820		631	435			36

*Percent cell fill considered in computations.
**Based on average of three tests of 200 feet each.
***Only 11/64 plates available.

Table 5.—Comparison of various planters at 6 miles per hour (grease board test), Brawley, Calif., test.

Planter	Seed used per acre* Actual pounds of 7/9	Theoretical cells per foot row	Percent actual cell fill	Actual number of sprouts per 100 feet of row**	Total potential sprouts per 100 feet of row	Seed pieces larger than 6/64 remaining per 100 feet of row	Total sprouts per 100 feet of row after passing metering device	Sprouts lost per 100 feet of row		Total sprouts per 100 feet of row after passing metering device; as percentage of theoretical seeding
								No.	Percent	
J. D. Low Can (curved tube)	2.32	2.6	193	502	492	417	307	125	25	141
	3.14	4.3	165	711	697	671	510	187	27	119
	3.36	6.4	116	742	727	707	544	183	25	85
	4.50	8.1	125	1,015	995	968	755	240	24	93
	2.97	10.0	66	662	649	635	419	230	35	42
J. D. No. 55 (long curved tube)	1.88	2.6	157	409	401	394	339	62	15	130
	2.70	4.3	142	610	598	587	487	111	19	113
	3.38	6.1	125	763	748	740	585	163	22	96
	3.73	7.4	113	834	817	810	664	153	19	90
	3.86	9.4	92	863	846	840	622	224	26	66
Cobbley	1.86	2.6	155	404	396	389	306	90	23	118
	2.76	4.3	145	624	612	565	503	109	18	117
	3.46	6.0	128	769	754	690	594	160	21	99
	4.25	7.5	125	935	916	843	750	166	18	100
	4.4	9.0	110	994	974	885	673	301	31	75

*Percent cell fill considered in computations.
**Based on average of three tests of 200 feet each.
***Only 11/64 plates available.

is noted. The John Deere No. 55 long curved tube seems to have a slight pattern advantage over the shorter straight tube.

A strange pattern evaluation came from a study of the Rassmann planter using different sized seed in their 11/64 inch rotor. (Figure 4). Note that the pattern is better using 7-10 seed at high cell fill than when closer graded seed was used. We were somewhat surprised at this result.

A cell fill study was made (Figure 5) of several drills at 3 m.p.h. showing a John Deere average of around 150 percent, Cobbley 140 percent and I. H. C. No. 40 at 130 percent. In all of these there is a definite decrease at higher seeding rates.

It is an accepted fact that the smooth tube gives a better pattern than the flexible spiral tube (Figure 6) but we also made a comparison from our laboratory studies. The difference at 2 m.p.h. is shown as about 30 percent and at 3 m.p.h. reading values differ by about 25 percent. Due to the fact that these are laboratory differences the field differences will most surely be more because of air current interference with the flexible spiral tube.

A good study of seed damage was made using a 6/64th screen and calling the plusses undamaged seed and the minuses as the damaged units. Table 3 shows the Cobbley to be the worst offender in this category as compared with the various other commercial drills. The John Deere No. 55 can seems to be acceptable from this angle.

The laboratory germination data on seed used is shown in Table 6.

Table 6.—Imperial Valley seed comparison test at 3 m.p.h.

Seed	Units per pound	Normal sprouts per viable seed ball	Sprouts per 100 seed balls	Percent singles	Percent emergence on potential
U. S. No. 22 7-9 Whole	60,663	1.42	88	70	66
U. S. No. 22 7-9 Segmented	60,288	1.27	80	79	62
U. S. No. 22 7-10 Segmented	56,592	1.39	113	69	56
U. S. No. 22 11-13 Pellets (from 7-9 segmented)	5,700	1.13	52	82	85

We are not prepared to make any statement condemning or appraising any particular drill but the facts disclose that there are apparent weaknesses in all of the drills which we tested and that further work needs to be done to develop improvements in their performance.

An Electric Device for Recording Distribution of Seed From Planters

A. A. SCHUPP[1]

In cooperation with Dow Chemical Company, the Farmers and Manufacturers Beet Sugar Association has developed an electronic device for recording the distribution of seed from a planter.

This device consists of:

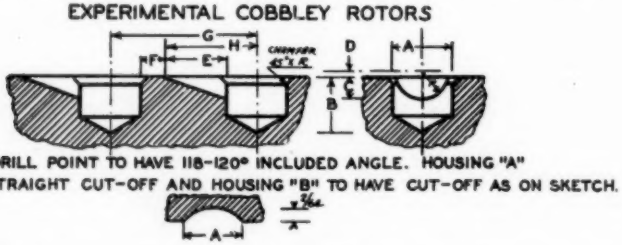
1. A flat surface microphone placed directly beneath the discharge tube of a planter and at a 45-degree angle to the tube. Seeds fall from the tube, strike the microphone disc, and then because of the 45-degree angle bounce clear. This method permits a slight error because a seed falling from one side of the tube must fall a distance equal to the inside diameter of the tube farther than a seed falling from the other side of the tube. However, the time necessary to fall this additional fraction of an inch is not sufficient to interfere with the proper interpretation of the results.

2. The sound impulse of the falling seed on the microphone is transmitted to an electronic amplifier (Brush Development Co. Type OA-2).

3. The amplifier sound impulse is then transmitted to an oscillograph (Brush Development Co. Type PO-4).

4. The impulses are then recorded on the oscillograph paper in the form of a staggered line, a peak being recorded as a seed piece strikes the microphone. The heavier the seed the greater the sound impulse, with a correspondingly longer peak recorded on the oscillograph paper.

By determining the rotor r.p.m. and the travel of the oscillograph paper in feet per minute the number of impulses which should occur in 1 foot of oscillograph paper can be calculated, as well as the dis-



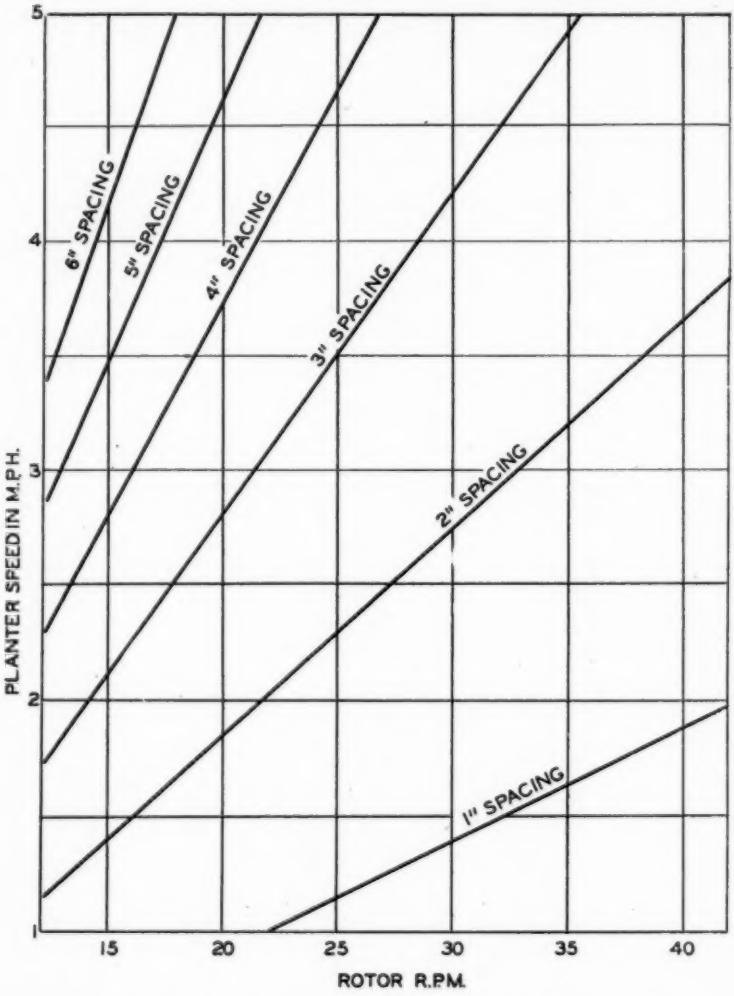
[1]Executive Secretary, Farmers and Manufacturers Beet Sugar Association, Saginaw, Mich.

tance between impulses. Thus the actual number of seed pieces metered per revolution of the metering device can be determined, along with the actual seed pattern and spacing design as recorded on the oscillograph paper.

Rotor No.	For seed size	For use in housing	Dimensions in 64ths									
			A	B	C	D	E	F	G	H	K	R
Ex-1	7-9	A	10	10	3	2	10	4	24	15	1	5
Ex-2	7-9	B	10	8	3	2	10	4	24	15	1	5
Ex-3	11-13 P	A	14	14	5	2	8	2	24	15	1	7
Ex-4	11-13 P	B	14	12	5	2	8	2	24	15	1	7
Ex-5	11-13 P	A	13½	13½	5	2	8	2	24	15	1	7
Ex-6	11-13 P	B	13½	11½	5	2	8	2	24	15	1	7
Ex-7												
Ex-8												
Ex-9												
Ex-10												
Ex-11												
Ex-12												
Ex-13												
Ex-14												
Ex-15												
Ex-16												
Ex-17												
Ex-18												

F. & M. beet sugar—Saginaw.

	Test No.	Rotor No.	Cut-off style	Clearance Between cut-off and rotor	Seed or pellet size	Pellet base	Rotor r.p.m.	Percent Broken in rotor	Percent cells filled	Seeds per 100 cells
Pelleted Segmented	1	Factory built		.005	7-9	.....	13.7	21.76		148
	2	Factory built		.005	7-9	.....	34.0	24.08		137
	3	Ex-1	A	.003	7-9	.....	34.0	19.06		107
	4	Ex-1	B	.003	7-9	.....	34.0	14.90		134
	5	Ex-2	A	.003	7-9	.....	34.0	9.63		99
	6	Ex-2	B	.003	7-9	.....	34.0	14.68		89
	7	Ex-2	B	.003	7-9	.....	13.7	21.54		154
	8	Ex-3	A	.003	11-13	Flyash-feldspar	34.0	17.86		94
	9	Ex-3	B	.003	11-13	Flyash-feldspar	34.0	14.51		98
	10	Ex-4	A	.003	11-13	Flyash-feldspar	34.0	35.12		94
	11	Ex-4	B	.003	11-13	Flyash-feldspar	34.0	13.52		88
	12	Ex-5	A	.003	11-13	Flyash-feldspar	34.0	18.78		99
	13	Ex-5	B	.003	11-13	Flyash-feldspar	34.0	17.26		94
	14	Ex-6	A	.003	11-13	Flyash-feldspar	34.0	29.58		89
	15	Ex-6	B	.003	11-13	Flyash-feldspar	34.0	14.48		93
	16	Ex-6	B	.003	11-13	Flyash-feldspar graphite coat	34.0	7.96		101
	17	Ex-6	B	.003	11-13	Flyash-feldspar graphite coat	13.7	9.05		100



Indications are that each Cobbley unit (consisting of rotor and housing) has an optimum rotor rp.m. at which optimum speed it dispenses approximately 100 seeds per 100 cells and causes the least damage to the seed. When this optimum rotor r.p.m. has been determined for an individual Cobbley unit and the desired seed spacing is known, the correct planter speed in m.p.h. for the optimum rotor speed can be determined from the chart shown here.

Methods of Describing Regularity of Seed or Seedling Spacing

F. A. Brooks and G. A. Baker[1]

What method is best for measuring the regularity of spacing of seeds or seedlings is still not agreed upon. Only a few individuals are concerned with the setting-up of the various methods, so it should be possible to establish a uniform practice if that is desirable. It is essential first to understand the differences in procedure of the different systems. Then in view of the different objectives it is necessary to decide how much extra work is justified beyond the simplest procedure by the advantages of uniform, general practice.

Three Typical Methods of Field Counting.—McBirney[2] single-handed, counts up along a 100-inch scale: (a) total number of seedlings, (b) total beet-containing inches, which is called "percent stand", (c) number of inches with only one seedling, called "singles", and (d) the largest gap in inches. This requires three trips along each 100 inches, but writing down the figures only at the end of each pass. The information so obtained is adequate to specify thinning by Mervine's[3] formula and gives a hybrid four-element indication of the distribution of spacings: numbers of scalar inches with zero, one and two or more seedlings per scalar inch and the longest run of blank inches. Such a field count is a sufficient procedure to describe irregularity relative to past experience as long as the mean spacing distance is about 1 inch, but the count tends to all singles as the mean spacing distance increases relative to the scalar unit.

Cannon[4] or Brooks classifies seedling count per inch and blank inches per space in a single pass along the tape but needs either an extra man to write for the observer or else a mechanical marker to keep place while the observer is writing down each count as he proceeds along the tape. Since no return pass is necessary, the ground covered per man-hour is not much different in this procedure than the former. The data obtained, however, gives all that McBirney wants and in addition provides a full-range picture of seedling distribution from the closest bunching to the biggest skip. This system of field counting requires slightly more office work (in totaling) to get McBirney's figures and modified statistical treatment to get the coefficient of variability.

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[1]Agricultural Engineer and Assistant Statistician, University of California Agricultural Experiment Station, Davis, Calif.

[2]McBirney, S. W., Senior Engineer, USDA, Fort Collins, Colo. (See his letter 2/24/45 to Roy Bainer).

[3]Mervine, E. M., Agricultural Engineer, Colorado A & M College, Fort Collins, Colo.

[4]Cannon, Rowland, Utah-Idaho Sugar Company, Salt Lake City, Utah.

McCreery[5] or Baker, by noting the number (or absence) of seedlings per inch in successive order, obtains all the information previously mentioned and in addition gets the order of occurrence. Their record would show the full range of spacing distribution and besides this would reveal possible successions of skips and multiples which is a characteristic more objectionable than the same skips or multiples evenly spaced. This method of field counting is as fast or faster than the Cannon-Brooks classifying count but requires much more office work in developing the data.

Various Objectives of Field Seedling Count.—Mervine's field counts in connection with his studies of thinning far antedate our observations of seed spacing in our investigation of planter performance. Fundamentally Mervine's interest in seedling stands calls for a different criterion than for studies in the irregularity of spacing. His present field count procedure is naturally an amplification of previous seedling stand counting to include indicators of irregularity in spacing. This is sufficient for his purpose but not complete enough for direct comparison with our observations.

The method of counting adopted in Davis 3 years ago was based on "standard deviation", σ, the usual statistical measure of spread of distributions. This criterion of irregularity varied with mean spacing distance, s, so we took the next usual step and adopted "variance" as the measure of irregularity. This is the square of "coefficient of variability", σ/s.

The method of interpretation now proposed by Dr. Baker is a sound mathematical equivalent of our earlier attempts to measure displacement from expected position (of mechanical opportunities). This also is based on variance, but he calls the σ_D/s "coefficient of discrepancy, D", to distinguish it from the orthodox interpretation of the previous method. Unfortunately, Baker's uniform positions cannot be exactly identified with mechanical opportunities and the coefficient, therefore, is not independent of length of run.

There has always been some question in our own planter problem, however, as to what statistical criterion would be most appropriate. Thus the need for review goes beyond the differences between methods used by the USDA and ourselves. Two years ago when we were debating whether standard deviation was the best measure of irregularity of seed placement, the use of this common criterion was questioned because it did not penalize clusters of seedballs to the degree they seemed objectionable in comparison with skips. We suggested

[5]McCreery, N. R., Agriculturist, retired; Great Western Sugar Company, Denver, Colo.

meeting this by the additional ⅓ application of the Chi-Square criterion, expecting that experience would eventually lead to a proper choice of proportional weight. Now, with the lighter seeding rates and more precise planters, clusters are no longer a serious problem and some experts ignore them altogether. They go so far as to ask for simply "how many inches per 100 have one or more seedlings?" This could be answered readily by the Mervine-McBirney count of "beet-containing inches", possibly omitting their usual "single-seedling inches."

However, the very fact that there was a change in viewpoint (which perhaps made obsolete our specialized method of interpretation) is an argument in favor of using some standard statistical measure. The choice therefore lies between a standard description of irregularity and a shorter method using only part of the standard observations. Rather than abandon standard procedures we prefer to omit refinements previously called for, because as seed spacing increases the inherent error of measuring spacings by whole inches decreases and the uncorrected determination approaches the true standard deviation.

The established USDA method serves as a measure for irregularity of spacing because there is a natural relation between singles, multiples, and gaps under standardized conditions. McBirney suggests that "after making a number of counts, an average of seedlings per beet inch (excluding singles) may show that the multiple seedling inches contain a constant number, either 2 or slightly more, and the total count of seedlings may be eliminated, calculating this from percent stand number of singles". We believe the same type of comparison might be used to correlate loosely the USDA method with ours. It seems to us, however, that the natural distribution changes with the treatment of the seed and seedbed, so one would always have to judge relative to past experience for given conditions.

For instance, at a 2-inch spacing distance, seed sheared to one germ each would produce 100 percent singles. The McBirney count would show identical "singles" and "percent stand". There would be no indication of the irregularity of gaps except the one largest. Only total skips would show as unfilled inches per 100 inches. For the same seed but planted at a 1-inch spacing distance, the USDA rating would show some doubles (where the seedballs were close to the inch-lines), many singles, a higher "percent stand", and, by subtraction, some blanks. The spacing in both cases might be practically perfect yet the count ratings would be very different. The USDA system noting blanks, singles, and doubles unrelatedly, would give a faulty indication of irregularity of spacing. We therefore think that whenever irregularity is to be measured one should use a more com-

SAMPLE TALLY AND CALCULATION FORM FOR SEED DISTRIBUTION

PLANTER: Cobbley — TEST NO: 7c p 1 of 2 pgs.
LOCATION: A.E. Lab - Davis — DATE: 1-14-44
SETTING: 3.1 lbs/A. of 2 m.p.h — OBSERVERS: Lewis & Bainer
SEED: U.S. 33-1415 thru 9 over 3/64
REMARKS: Dropped thru a 3 5/64" Chrome-moly Tube 15" Long

A. TALLY: CATEGORY:	n/q	4/q	3/q	2/q	1/q	0q0	1q0	2q0	3q0	4q0	nq0	TOTAL
BOARD No. 1				1111	7961 7961 7961

prehensive field counting system than the Mervine-McBirney-USDA but possibly a more abbreviated office treatment than we previously recommended. Whether the more complicated position-counting of McCreery-Baker is worthwhile depends on how much need there is for more emphasis on the successive order of deviations.

Office Work in Treating Field Counts.—One of the main difficulties in rating planter performance was that the usual statistical procedures (including Mervine's) gave answers that varied with planter speed. Some of this variation is inherent in that with greater speed there is less crossing of seed trajectories as they issue from the drop tube, but most of the change was in the dimensional nature of the statistical criterion. Therefore we recommend using the non-dimensional form of variance, namely

$$\sigma s^2 = \sigma^2/s^2 = \frac{1}{Ns^2} \Sigma\ (v\text{-}s)^2. \qquad (1)$$

This is the square of the usual "coefficient of variability" (σ/s), and gives a constant magnitude for a given distribution regardless of the size of the dimensional unit (if small enough to distinguish the irregularities). The proviso on the size of dimensional unit becomes less important as spacing distance increases retaining the scalar-inch as the unit.

All field counting procedures record the total count, N, and the length of row, L; hence the mean spacing distance, $s = L/N$, is always obtainable. Complications arise only in measuring the variable spacing distance, v, and in calculating the squares of the deviations from the mean, $(v\text{-}s)^2$.

Baker's criterion to include successive order uses the same basic system of deviations squared, as in the foregoing equation, but measures deviations of observed position X_i from the position, i times s, where the seedling would be found if all were in uniform successive steps. His equation for coefficient of discrepancy is

$$D = \frac{\sigma_D}{s} = \sqrt{\frac{1}{Ns^2} \Sigma \left\{ X_i - (is + k) \right\}^2}. \qquad (2)$$

This is almost the same form as equation (1) but requires a calculation of best starting position, k, of the scalar-inch tape.

Once the classified or ordered field data is obtained, the closeness of approach to a true measure of irregularity depends on the method of working up the data, except that we are always faced with the inaccuracy due to the crudeness of using a scalar-inch as the least unit of measurement. If the accuracy of shortcut methods is judged by difference in result from that obtained by the full treatment (of

the same criterion), the investigation of inaccuracy is most specific when applied to precise, successive observations of spacing distance. McBirney has one set of data on seed placement observed to the nearest 1/8 inch, and we have a few studies of the John Deere and Rassmann planters where seed spacing was measured to the nearest 1/10 inch. We do not know of field measurement of seedling spacing measured closer than in scalar-inch units with notation of multiples per inch.

Because all field counts are based on the scalar-inch we have interpreted the spacings between multiple seeds per inch as if in equal fractions: one-third inch each for three seeds in 1 inch. Then for the distance between seeds in adjacent scalar inches or separated by blank inches we have heretofore calculated, as recommended by Cannon, the mean "end correction", that is the average distance between seeds across a scalar-inch line. This is 1 inch if the beet-containing inches are all singles, but would be only one-fourth inch if all the beet inches had four seeds. This refinement fades in importance as mean spacing distance increases, so it may now be practical to omit the calculation of end correction.

To investigate this possibility we have recalculated about 40 examples and find that the variance tends to be higher but there are few changes in the order of rating. Table 1 gives eight samples which best show the trend as mean spacing distance increases.

Possible Drastic Simplification of Rating Method.—If the industry is now willing to work in units of "beet-inches", that is to observe only $\Sigma n'$ as the number of scalar inches containing one or more seedlings, and ignore the "or more", the statistical procedure would be very simple for determining the irregularity in the spacing distribution. For this the Cannon-Brooks field counting would need to note only the positions of the blank inches.

Table 1.—Examples of simplified determinations of variance of seed-spacing distributions.

	Graded size inches	Total count N	Mean spacing s inches	Variances		
				σ_s^2 basic 1/10 in.	σ_{ss}^2 end-corrected 1 inch	simplified 1 inch
John Deere plate 5/8/43		1122	1.386	0.780	0.657	0.728
		1110	2.81	0.709	0.671	0.682
		1028	5.64	0.630	0.624	0.625
		1002	11.94	0.348	0.344	0.344
Rassman whole seed 8/28/43	8-7/64	379	1.03	.....	0.366	0.576
	9-8/64	277	1.42	.....	0.208	0.262
	10-9/64	189	2.00	.....	0.271	0.277
	11-10/64	81	4.88	.....	1.989	1.989

Summary

We have attempted to explain the various methods now practiced for rating the regularity of seed or seedling spacing. The needs of the investigators are different and naturally call for the use of different statistical units of measurement. More detailed field observations are recommended to the USDA if the ratings by different systems need to be made inter-convertible. Considerable simplification is feasible in our office procedure, especially if mean spacing distance increases. Drastic simplification of both field count and office practice is possible if the industry is no longer interested in the number of seedlings in a given scalar inch.

Appendix: Scalar-Inch Method of Determining Seed or Seedling Distribution

As a quick approximate method of rating single seed planter performance at a given seeding rate, counts with 100-inch scales ruled in inches can be made and interpreted as follows:

A. Place a 100-inch scale close to the row, to spot each seed or seedling within the (extended) rulings every inch. (Occasionally the projected inch lines will pass through a cluster of seeds, but the divided cluster will still yield reliable results).

B. For each inch, count the number of seeds or seedlings, or note their absence on a data sheet such as in example shown. Count a row long enough to include at least 400 seeds or seedlings.

C. Sum and calculate as outlined on example tabulation form to get a dispersion factor (approximate standard deviation), which is an indicator of seed or seedling distribution at the given seeding rate. Small values of this dispersion factor show good spacing. The dispersion factor is usually smaller for higher seeding rates and in general can be represented by a straight line over a considerable range of seeding rate.

D. In addition to laboratory tests of seed distribution, planters should be field-tested (with bags at discharge opening), getting at least five runs of 1/100 acres each, taken occasionally during a travel of more than 1 mile, in order to observe (a) steadiness of feed-rate (in pounds per acre) and (b) seed damage (percent passing minimum screen of trial seed, by weight).

E. First simplification feasible when s exceeds 1 inch) is to omit end-correction sub totals C′ and E′, taking F=1.00. The next simplification is to omit correction for expected count H′, P′, and R′ but this penalizes cases with b near 0.5.

Evaluation of Field Test Data For Comparisons of Sugar Beet Planters

S. W. McBirney[1]

Present development of sugar beet planting equipment and methods has as its objective the production of planted or thinned stands of sugar beets with a minimum of labor and cost which will be suitable for production and harvest. A simple method of evaluation of field test data for comparison of results obtained with different sugar beet planters is becoming more and more necessary as development work on the equipment continues and the planters are improved. No uniform or standard method of evaluation, particularly of seedling distribution, is now used throughout the industry and some of the methods which have been used either do not enable direct comparisons between planters because seeding rates or seedling stands differ or require considerable computation and are not readily understood and interpreted by many who are concerned with tests of planters.

There are two distinct objectives of tests of beet planters and planting methods. One is to investigate and improve the effectiveness of planters or methods on seed germination. The other is to investigate and improve those characteristics of planters which effect distribution of seedlings. These objectives are sometimes confused or lost sight of and a set of planter plots will be put in with equipment varying both characteristics of planters so that the results are interrelated, and clear cut differences in either seed germination or seedling distribution cannot be shown. In general it would seem desirable in making planter tests to study one variable at a time, for example, seed germination characteristics, and while so doing to keep all other variables constant, like seed distribution, seeding rate, seed, and speed.

Evaluation of Data on Germination Characteristics

In planter tests to investigate the effectiveness of planting equipment or methods on seed germination, we are interested only in one objective. That is to compare or increase the percentage of the viable seeds or germs which produce seedlings. Only a small percentage of the seeds which would have produced seedlings under greenhouse or seed laboratory conditions are germinated in many field plantings. In Northern Colorado under normal conditions the average percentage of the viable germs which produce seedlings usually ranges from 30 to 50 percent, though by improving germination conditions this has ranged up to 90 percent with exceptionally favorable conditions.

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[1]Bureau of Plant Industry, Soils, and Agricultural Engineering, U. S. Department of Agriculture.

A simple expression or comparison of the percentage of seedlings germinated from those possible from the seed planted is the only data evaluation necessary in this case. The measure which is being used for this planter characteristic is the percentage of field emergence which is the percentage of potential germination and gives a value directly comparable for different equipment or sets of germination conditions; data have shown that for segmented seed there is no correlation between percentage of field emergence and seeding rates used.

The only field counts which are therefore necessary for comparisons of this type of plantings are several counts of the number of seedlings per 100 inches of row. Seeding rates need to be determined carefully at the time of planting, and the potential or possible seedlings per 100-inch length of row can be calculated from the seeding rate and a laboratory germination test of the seed. The laboratory test should include both the percentage of germination of the seed segments and the number of sprouts produced per viable segment. The percentage of field emergence can be determined from the average of the seedling counts and the possible number of seedlings per 100 inches at the seeding rate used.

If desired, statistical analysis can be used to determine whether differences in percentages of field emergence are significant. Seedling counts on 100 inch lengths of row usually have considerable variation, the standard deviation averaging about 20 percent of the count in the seeding rate range used for segmented seed. This means that to show actual average differences of 10 percent between two counts as significant it will be necessary to make 32 seedling stand counts. Where several different germination treatments are compared and analysis of variance is used in the statistical analysis, less seedling counts per treatment will still show 10 percent differences to be significant. Probably not less than about 16 counts should be made on each treatment in any case and preferably 20 or 24.

Evaluation of Seedling Distribution Data

Planter tests to investigate the differences in seed and seedling distribution are the ones which present by far the biggest problem in evaluation of data. Several different methods of evaluating seedling or germination stands or seed distribution by planters have been used. The chief objective of one group of these methods has been to enable suitable set-ups of mechanical blocking or thinning equipment. The purpose of the other group has been to compare seed or seedling distribution of planters. Because of the major differences in methods being used, a standardized or uniform method could well be adopted.

Mervine (*1*)[2] developed the first definite method of evaluation

[2]Italic numbers in parentheses refer to literature cited.

of beet planter field germination stands in 1931 for use in set-up of mechanical blockers. It consisted of expressing the field germination stand as the percentage of inch-lengths of beet row containing one or more seedlings, the counts being 100 inches long, and the value came to be generally used as "percent stand." In 1936 and 1937 when development work on single seed planting was begun, I used first singles per 100 inches and later percentage of beet containing inches which were singles in seeking for a method of evaluating the planter data and comparing planters. In 1938 and 1939 when the grease board method of laboratory planter testing was developed, I used frequency-seed distribution curves for evaluating the planter data, using the percentage of seed spacings in a plus and minus band about the mean spacing as a measure (*2*).

In 1943 Brooks[3] developed a method of evaluation of seed or seedling distributions, using an approximation of the standard deviation of each set of data from a planting or grease board test as a dispersion factor. This method has been modified since by Brooks and Baker.[4] Cannon[5] developed a somewhat similar method in 1943, except that an approximation of the coefficient of variation or standard diviation divided by the mean spacing was used to evaluate the data. He uses it only for grease board tests, however, and has not suggested it for field planting data.

This last season we developed and used a modification of the method of evaluation used formerly on single-seed and segmented seed planter tests. With this method the percentage of the beet seedlings which are single plants is used as a measure of the quality of the planting. The planter which produces the highest percentage of singles, other things being the same, is considered to be the best and producing the best seedling distribution. A single plant is taken as one that is single in a 1-inch length of beet row; this is the commonly used measure of a single.

This method may not measure or evaluate the uniformity of seedling distribution as such perhaps, but it does measure that characteristic of a sugar beet planting in which we are most interested in connection with mechanized thinning, that is single plants. However, it does partially or indirectly measure seedling distribution as double seed-segments in planter seed cells and crossed trajectories as the seeds fall result in decreased percentages of single seedlings which are measured by this method. Furthermore the percentage of seedlings

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[3]F. A. Brooks, Agricultural Engineer, and [4]G. A. Baker, Assistant Statistician, University of California Agricultural Experiment Station, Davis, Calif.

[5]Royland M. Cannon, Agricultural Superintendent, Utah-Idaho Sugar Company, Toppenish, Wash.

which are singles or, as it is usually called, the percentage of singles is easily understood and interpreted, readily calculated from several seedling stand counts, and can be directly compared where seed, seeding rates, germination conditions, and planter speed are the same. The stand counts necessary are simple and can be made by one man; the office calculation is not difficult or elaborate. If desired, statistical analysis of the data can be made, and the differences required for statistical significance can be determined.

The percentage of singles obtained with any one planter set-up varies with different seed, seeding rates, sets of germination conditions, or planter speed. Therefore if different planters, or planters with different conditions or seed, are tested, the percentages of singles have to be adjusted along correlation curves before direct comparisons can be made. Tests were made this past spring which gave data for determining the relationships between the percentage of singles and the different variables so that procedures and curves have been worked out for making comparisons between planters even though the planting conditions were not kept constant. These are explained in the following pages, but in general when testing planters for uniformity of seedling distribution, it is desirable to keep everything else as nearly constant as possible.

The seedling or germination stand counts needed are made with a 100-inch counting stick graduated in inches with lines across the stick. No numbering of inches is necessary. The stick is laid down along a beet seedling row and the cross markings assumed to extend on across the beet row. A count is made of the total number of seedlings in the 100-inch length of row and recorded. Then a count is made and recorded of the number of single seedlings in the same 100-inch length, a single being only one seedling in a 1-inch length of row. With this method of counting, two singles may actually be less than 1 inch apart if they are in separate inch lengths of stick but on opposite sides of the dividing line. However, the method is commonly used and seems to work out satisfactorily, and if, when the stick is dropped at random for a count, several successive seedlings seem to occur on the dividing lines between inches, the stick can be slipped along a half inch or so before the count is started. This is seldom necessary and the stick should not be moved along the row after the count is started. The two counts, that is the total seedlings and the singles per 100 inches, can be made simultaneously after some practice if a hand counter or tally register is used. To do this the total seedling count is made mentally and whenever a seedling is encountered which is a single, the tally register is clicked. At the end of the 100-inch count, the mental count of total seedlings is recorded and the number of singles is taken from the tally register and recorded.

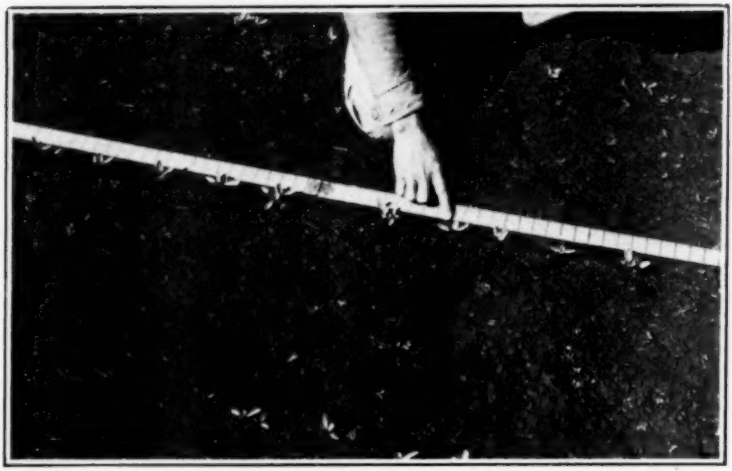


Figure 1.—The seedling stand counts needed for planter comparisons are made with a 100-inch stick graduated in inches.

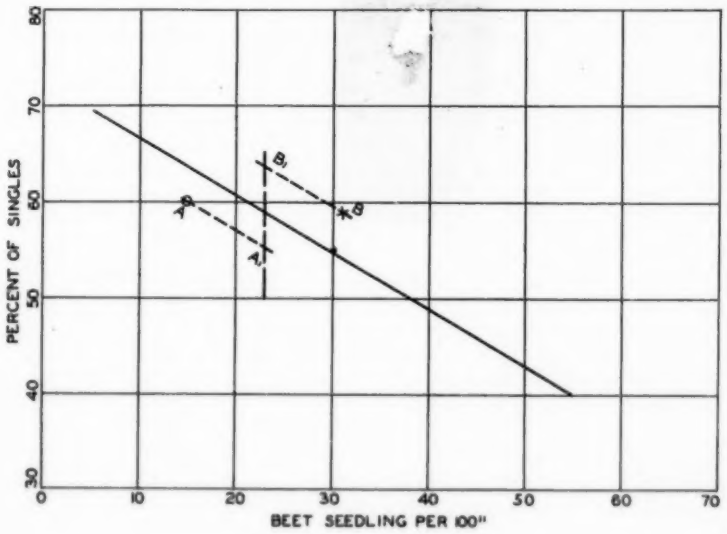
If the counts are to be used for determining set-ups for mechanical blocking or thinning equipment also, as is sometimes the case, a third count can be made of the beet-containing inches. If this is done the total seedling count should be made first and recorded and then the beet-containing-inch and singles counts made simultaneously using the tally register. This makes the beet-inch and singles counts conform since it is sometimes necessary to decide whether two seedlings are in the same or separate inches. This beet-inch count is not used in evaluation of the seedling distribution.

In making the stand counts, as in making them for the germination studies, 16 to 24 counts should be made on each planting, depending on the uniformity of the stands. With this number of counts and several plantings being compared, 10 percent actual differences can be shown to be statistically significant by analysis of variance of the data. The percentage of the seedlings which are singles in each stand count is calculated and all the percentages of singles for each planting are averaged. The average percent singles for different plantings can be compared directly if all planting conditions except the distribution are kept constant. It usually takes a difference of 6 or 7 percent to be significant at the 95-percent level of significance.

Usually all planting conditions cannot be kept the same and some further calculations are necessary to make direct comparisons between percentages of singles with different plantings. One of the things which affects the percent singles obtained with any particular planter

is the seeding rate used. With seed distribution mechanism and all other planting conditions the same, the precentage of singles decreases as the seeding rate increases. Theoretically this should not be true at very light seeding rates and with exactly spaced seed, but with the seeding rates normally used for segmented seed and the planters which have been developed so far with their occasional double seed segments and crossed seed drop trajectories, the decrease throughout the range used has been found to be practically a straight line decrease.

The relationship between the percentage of singles and seeding rate is shown in figure 2 which was prepared from a set of planter seedling distribution data this last spring. The data were analyzed by analysis of covariance to eliminate the differences from different planters, and the curve shows the average slope or decrease in percent singles as the seeding rate increases for all the planters tested. Equipment, seed, and germination conditions were kept constant for each planter test as the seeding rate was changed. The seeding rate is shown as seedlings per 100 inches rather than pounds per acre or seed cells or seed segments per foot because the stand count data are taken that way and the curve is more readily useable. On the set of plots from which these data were taken the precentage of field emergence averaged approximately 35 and with the 7/64 to 9/64 and 7/64 to 10/64 segmented seed used, the 2 pound per acre seeding rate (with 20-inch beet rows) produced about 11 seedlings per 100 inches, the



4-pound rate with its approximate 2-inch cell spacing about 22 seedlings, and the 6-pound rate 33 seedlings. The slope of this curve is –.6 which means that on the average for any of the planters tested the percentage of singles decreased .6 of 1 percent for each increase of one in the number of seedlings per 100 inches. In general the test data for any particular planter set-up when plotted would define another line parallel to the one shown on figure 2 and above or below it, depending on whether it was a better or poorer distribution than the average.

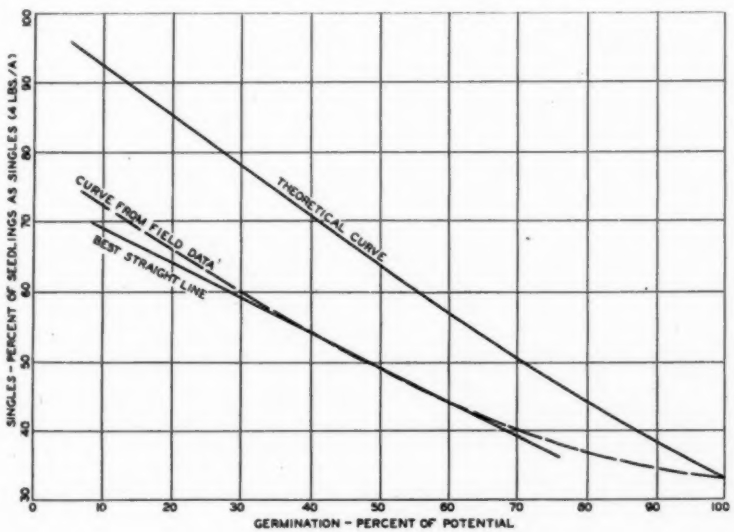
It can be seen from figure 2 that planter comparisons should be made at the same seeding rate or seeding stand. However, it frequently is not possible to secure exactly the same seeding rates with two planting mechanisms being compared. The proceedure for adjusting the percent singles to an average or desired seedling stand for direct comparison is as follows: Determine the difference between the observed seedling stand and the average seedling stand for all tests or the seedling stand at which comparisons are desired. Multiply this difference by .6 and add this product to the observed percent singles if adjusting to a smaller seedling stand or subtract it from the observed seedling stand if adjusting to a larger seedling stand. This is equivalent to following up or down from the observed percent singles, going parallel to the curve in figure 2 to the average or desired seedling stand for comparison.

For example, suppose the averages for two planters A and B are 60 percent singles at 15 seedlings per 100 inches and 59 percent singles at a 31 seedling stand respectively. Comparisons will be made at the average seedling stand of 23 per 100 inches. The difference between either stand at A or B and the average stand is 8 seedlings per 100 inches. This difference multiplied by .6 gives 4.8 which is added to B and subtracted from A. The adjusted percent singles for A is 55.2 percent at A_1 and for B is 63.8 percent at B_1. When these two adjusted values are compared, B produced 8.6 percent more singles, a difference which probably would be significant. The average slope of –.6 for the curve in figure 2 can be used for approximating other planter test comparisons. Other sets of data from planter tests in previous years have given slopes of –.64 and –.72 when similar sized segmented seed was used. Probably a better average slope to use when none has been determined is –.65. If seeding rates are not greatly different, the error in adjusting percent seedlings with any value from –.6 to –.7 would be small.

Another variable or condition encountered on planter seedling distribution tests which effects the percentage of singles obtained with any particular planter is the percentage of field emergence or potential

germination obtained. This is readily understood when we remember that all our segmented seed or seed processed in other ways contains a certain percentage of segments which contain double or multiple viable germs. If germination conditions are very favorable this double segment is more likely to produce a double seedling than if the germination conditions are poor.

The relationship between percent singles and percentage of field emergence has been determined from a set of data taken on one set of our planter plots last spring. This set of plots was planted with the same planter, seed, and planter speed. Nothing was changed which would change the seed distribution, but a number of changes, such as different depth of planting, different press wheels, and different furrow opener characteristics, were made which gave a wide range of percentage of potential germination. The data were analyzed and the curves showing the relationship are shown as the two lower curves in figure 3. One, as indicated, is the best estimated curve to fit the data. The other is the calculated best straight line and fits the data very closely through the range in which we are concerned. The slope of the straight line is –.51 which means that as the percentage of field emergence increases by 1 percent, the percentage of singles decreases by .51 of 1 percent. Where seeding rates and other conditions of planter seedling distribution tests are kept constant, but the percent of potential germination varies, the per-



centages of singles can be adjusted to an average or desired germination level by using the straight line curve or the –.51 slope of the curve. The procedure for adjusting the percent singles is the same as that previously described for adjusting percent singles to average seeding rates.

It may happen on some tests that adjustments in percent singles will have to be made because of differences of both seeding rates and field emergence. In this case the adjustment for different field emergence percentages should be made first and when the percent singles is adjusted to an average germination percentage, the seedling stand should be converted to the proportionate seedling stand at the average germination percentage. Then the adjustment in percent singles can be made for different seeding rates by using the seedling stand at the average germination percentage and proceeding as explained using figure 2.

The relationship between percent singles and percentage of potential germination was considered from the theoretical approach last fall by Leach.[6] In the absence of field data he considered the theoretical relationship between the two based on the assumption that seed germs of single and multiple germ segments had equal probability of producing seedlings in the field. The location of the upper curve of figure 3 is determined in this manner from the percentage of single and multiple viable segments in the seed used in this test. The seed was a 7/64 to 10/64 segmented seed with 51 percent of the viable segments as singles, 43 percent as doubles, and 6 percent as triples. As can be seen from the two curves of figure 3, the actual percentage of singles falls short of the theoretical. Apparently if germination or vitality or other conditions are favorable for one germ of a multiple germ segment to produce a seedling, there is a greater probability of the other germ producing a seedling than the green of a random single germ segment.

Another very evident factor which influences the percentage of seedlings which are singles is the seed used. If one 7/64 to 9/64 seed has 80 percent of the viable seed units as singles and another has only 60 percent singles, it is obvious that a planter using the seed with 80 percent singles will produce a higher percentage of single seedlings, other things being equal. One set of our planter tests last spring contained plantings with a number of different seeds used in the same planter. All variables except seed size and plate to accommodate the seed were kept constant. The data from this planting enable a determination of the relationship between percentage of singles and

[6]L. D. Leach, Associate Plant Pathologist, University of California Agricultural Experiment Station, Davis, Calif.

the sprout count of the seed. All seed was used with plates having cells 1/64 inch larger in diameter than the largest size seed, that is 11/64 inch cells for 7/64 to 10/64 seed, and so on. As most of our processed seed, that is segmented, decorticated, or screened seed, contains some triples, it is more convenient and exact to express the sprout count of a seed as the average number of sprouts per viable unit, for example 1.45, rather than as the percent singles.

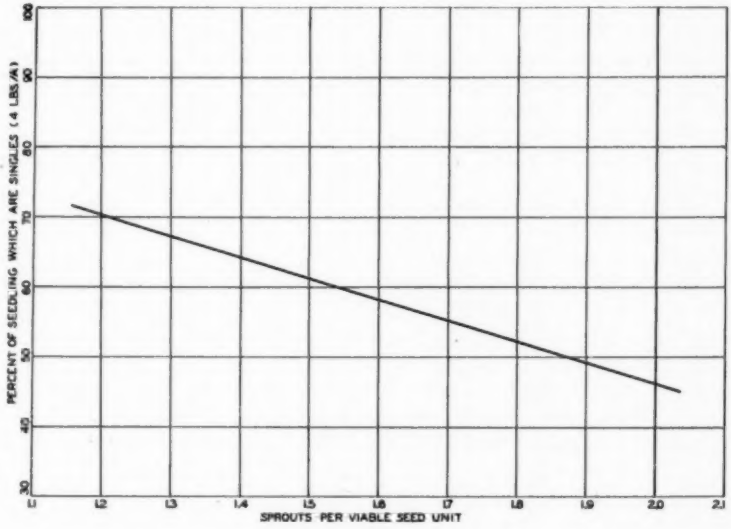
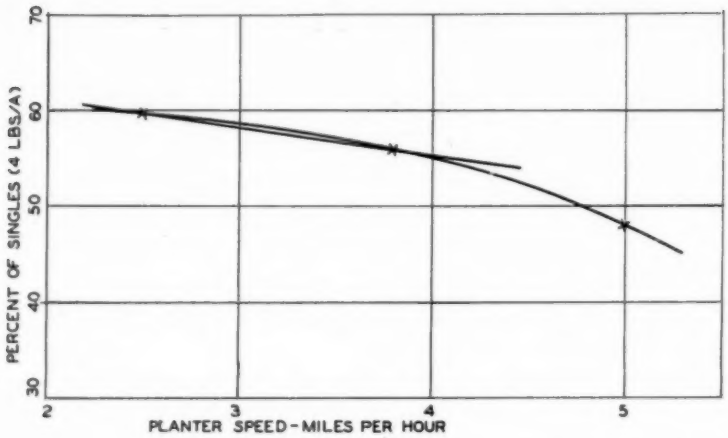


Figure 4 shows the relationship between percent singles and sprout count of seed as determined from this set of data for a 4 pound per acre seeding rate.

Curves for lighter or heavier seeding rates would be above and below that shown. The data show that throughout the range of sprout count in which we are concerned, a straight line seems to represent the relationship very well. The slope of the curve is –30.0 which means that as the sprout count increases, for example from 1.0 to 2.0 sprouts per viable seed unit, the percentage of the seedlings which are singles decreases 30.0 percent. In a more usable form the relationship is 3.0 percent decrease in percent singles for each increase of .1 in sprouts per viable segment. With this relationship it is possible to make approximate direct comparisons between percent singles obtained with different planters using different seed by adjusting the percent singles as explained for adjusting percent singles with different seeding rates.



The percentage of singles obtained with a planter also varies with changes in planter speed. Figure 5 shows the relationship as determined from our last spring's planter data. The percentage of singles drops off faster as the planter speed increases, but at speeds ranging up to around 3½ miles per hour the decrease in percent singles as planter speed increases approximates a straight line with a slope of –2.9. This means the percentage of singles decreases 2.9 percent as the planter speed is increased 1 mile per hour in this range, other things being equal. This is an adjustment of percent singles which should not have to be made because planter speeds can be kept constant for a set of plots. However, it is of practical value to know that planters produce smaller percentages of singles as planting speeds increase, particularly at higher speeds of 4 to 5 miles per hour.

This method of evaluation of planter seedling distributions may seem to become overly complicated after consideration of the above relationships between percent singles and planting conditions. However, it should be remembered that the use of some or all of the adjustments in percent singles can be avoided if every effort is made to keep all other planting conditions constant while planter seedling distribution is being investigated. These adjustments are explained here to show that they can be made and how they are made in case it is necessary.

A brief explanation should be given of why we are using the percentage of seedlings which are singles rather than the formerly used percentage of beet-inches which are singles. The germination stand counts for the latter can be more rapidly made and the use of a slower

stand count should be justified to be accepted. Data from different plantings have shown that with either method of counting, the percentage of singles decreases as the seeding rate or seedling stand gets heavier. Therefore comparisons should be made at the same seeding rates, and direct comparisons without adjustment of percent singles can be made only when the seedling stand counts are used.

A simple example will best illustrate this point. Suppose each of two planters puts in 4 pounds of seed and produces 25 seedlings per 100 inches of beet row. One gives 17 singles and 4 doubles and the other 9 singles and 8 doubles. The planter with 17 singles has 21 beet-containing inches of which 81 percent are singles. The other planter has 17 beet-inches of which 53 percent are singles. No direct comparison is possible because the beet-inch stands are different. However, with the first planter 68 percent of the 25 seedlings are singles, and with the second 36 percent of the 25 seedlings are singles, and a direct comparison is possible.

In comparing the percent-of-singles method of evaluating planter seedling stands with that using the combination of standard deviation and chi square or the standard deviation alone, it seems there are several objections to the latter which are overcome by the former. In the first place the counts required by the latter are considerably more elaborate, take two men, and are much slower to make. With the other method counts can be made by one man in one pass along the row when using a tally register and only two entries need be made per 100-inch count. Then the office calculation for the percent-of-singles method is simpler, particularly so if the planter tests are made as they should be, keeping all variables constant except the one being investigated. If variables develop, the most likely being percentage of field emergency, with different planters using different furrow openers, planting depth, press wheel type, or press wheel presure, the adjustment of percent singles can be made and the calculation is still shorter and simpler than of the standard deviation and chi square.

After it is calculated, the dispersion coefficient, which is used for comparing distributions with the standard deviation-chi square method, is not readily understandable or interpretable to many who are making planter tests. On the other hand the percentage of singles is quite readily understood and can be interpreted in relation to thinning. Furthermore, if it is desired to make statistical comparisons of results after the data are analyzed, differences required for statistical significance at the 95- or 99-percent level cannot be determined for the standard deviation-chi square method of evaluation, but they can be determined with the percent-of-singles method.

Another major objection to the use of a method of evaluation of field distributions of seedlings which uses the standard deviation is that the frequency-distribution curve of seedlings spacings is very badly skewed. The curves for seed distributions on a grease board are badly skewed to begin with and in the field the seedling distribution curves are much worse because of gaps resulting from failure of seed to germinate. The result is that the major portion of the standard deviation or its square, the variance, is made up of the data from a few large gaps.

A specific case will best illustrate the point. These data are taken from a typical planting of 7/64 to 10/64 segmented seed in a good plate planter at 4.33 pounds per acre. The cell spacing or forward travel of the planter per cell was 2.18 inches but the cell fill was 118 percent so the average seed spacing was 1.84 inches. Sixteen 100-inch counts on a total of 133 feet of row showed 386 seedlings or an average seedling spacing of 4.15 inches. The standard deviation of the seedling distribution calculated according to Cannon's method was ± 5.596 and the variance or square of standard deviation was 31.32. Forty-eight percent of this variance resulted from six gaps of 24, 29, 32, 37, 38, and 45 inches in the row. Seventy percent of the variance came from gaps of 15 inches or over when the average seed spacing was 1.84 inches. A grease board test with this planter did not show any skips greater than 7 inches at this seeding rate and skips over 5 inches rarely occurred.

These large gaps are faults of germination, when the seed is not being abnormally ground or otherwise damaged and it was not in this planting, and a planter distribution should not be penalized for poor or ununiform germination conditions. Therefore to use a value for evaluation of the seedling distribution nearly half of which results from 1.6 percent of the seed spacings or six seedling gaps, the smallest of which is 13 times the average seed spacing, does not seem justified. This argument is applied here only to field seedling stands and not to grease board tests. On the grease boards, the gaps are a result of poor seed distribution.

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Results of Mechanical Thinning Trials of Sugar Beets at Fort Collins in 1945[1]

E. M. MERVINE[2]

Seventy-eight percent of thinning and hoeing labor may be saved by "mechanically thinning" sugar beets. Some loss in yield may be sustained by mechanical thinning, but if the grower is anxious to maintain a high yield he may accomplish this and still use only 48 percent as much thinning and hoeing labor as is customary with the usual hand methods.

Plots cross blocked, then thinned with a long handled hoe and subsequently cross cultivated required only 31 percent as much thinning labor as the check plots of hand blocking and thinning but suffered a 9-percent decrease in yield.

The object of the first trial was to compare four methods of thinning beets under varying conditions of beet stands. Beets were planted at 2, 4, and 6 pounds of segmented seed per acre, which means approximately 4, 8, and 12 seeds per foot of row. An excellent seedbed caused an unusually high germination; in one case 94 percent of the viable germs in the seeds actually made plants.

The trial was planned with replicated plots to have the heavier seeding rates thinned in four ways: (1) Hand blocked and thinned; (2) machine blocked followed by long handled hoe thinning; (3) long handled hoe thinning; and (4) machine thinned.

The low seeding rate—four seed balls per foot of row—had only two treatments: (1) No thinning; and (2) long handled hoe thinning.

The labor time involved was checked for both thinning and subsequent hoeing.

Two other trials were incorporated, one to compare 20-inch, 30-inch, and 40-inch rows. In each of these replicates an attempt was made to maintain a reasonable approach to the same population per acre—this meant the 30-inch rows were supposed to have 150 beets per 100 feet of row as compared to 100 beets per 100 feet of 20-inch row.

The third trial compared cross blocked, long handled hoe thinned and subsequently cross cultivated beets with the customary hand blocked and thinned beets. Here the labor for thinning and hoeing

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[1]Scientific Journal Series Paper No. 212, Colorado Agricultural Experiment Station.

[2]Agricultural Engineer, Colorado Agricultural Experiment Station, Fort Collins, Colo.

Table 1.—Results of mechanical thinning trials at Fort Collins, Colo., 1945.

Seeding rate, seeds per foot	4		8				12					
Percent potential	94		85				92					
Beets per 100 inches of row	31		57				92					
Percent germination stand	22		38				53					
Singles per 100 inches	14		22				24					
Average maximum gap, inches	12		7.5				5					
Thinning method*	A	B	B	C	D	E	B	C	D	E	30 inches E	40 inches E
Hills per 100 feet	264	145	136	130	116	134	136	135	125	119		
Percent singles after thinning		62	50	63	61	96	24	58	62	81		
Time thinning, man-hours per acre	0	6.0	9.0	0.5	6.0	23.0	11.7	.5	6.0	26.1		
Time hoeing, man-hours per acre	0	7.5	6.8	7.6	6.3	5.0	8.3	6.4	5.6	5.5		
Total time, man-hours per acre	0	13.5	15.8	8.1	12.3	28.0	20.0	6.9	11.6	31.6		
Harvest												
No. marketable beets for 100 feet	174	139	130		108	104	140	123	127	103	149	168
No. unmarketable beets for 100 feet	102	28	34	30	20	5.	47	46	24	5.	15	12
Tons marketable feets per acre	11.1	12.7	11.7	11.5	11.9	12.6	11.2	11.1	11.5	12.2	11.1	9.8
Tons unmarketable beets per acre	1.4	.49	.46	.48	.34	.11	.72	.71	.36	.07	.12	.12
Total tons per acre	12.5	13.1	12.3	12.2	12.7	11.9	12.3	11.2	9.9			

*Thinning methods
A. Nothing
B. Long handled hoe only
C. Machine only
D. Machine followed by hoe
E. Hand block and thin

Table 2.—Mechanically cross blocked beets followed by long handled hoe thinning and subsequent machine cross cultivation.

Thinning labor 31 percent of hand thinned plot Hoeing labor 80.5 percent of hand thinned plot		
After-thinning population for 100 feet, machine		122
After-thinning population for 100 feet, hand		107
Percent singles	machine	66
Percent singles	hand	93
Yield tons per acre	machine	14.98
Yield tons per acre	hand	16.50
The difference in yield is statistically significant.		

was compared for the two methods, and at harvest the yields of each plot were measured.

The results of the mechanical thinning plots were:

(1) The highest yield was obtained with the lowest seeding rate where the total thinning and hoeing labor was only 48 percent of the check hand-thinned plot.

(2) In the higher seeding rates there was no significant difference in yield between the three "mechanical thinning" methods but all three yielded about 9 percent under the check hand-thinned method.

(3) Long handled hoe thinning resulted in a lower percentage of singles than machine thinning; this was very significant in the heaviest seeding rate where the mechanical thinner cut out 5⅝ inches of row and left a ⅜ inch block—a much smaller block than the hand laborer could leave.

(4) The loss in yield of the cross blocked and subsequently cross cultivated plot as compared with the hand blocked and thinned field was 9.02 percent but was largely compensated for by a saving of 69 percent of the thinning labor and 19.5 percent of the hoeing labor.

(5) The loss in yield in the "down the row" mechanically thinned plots was also 9 percent but in one method saved 78 percent of the thinning and hoeing labor.

Sugar Beet Populations in Relation to Yields

G. W. Deming[1]

Mechanization of operations in the culture of the sugar beet crop has top priority in sugar beet research today. The harvest of the crop by machines is apparently just around the corner. Hence there remains the elimination of hand thinning as the major requirement for the sugar beet to become a farm crop grown by typically American methods instead of an extensively grown truck crop. As mechanized operations are introduced to eliminate hand work in thinning sugar beets, the stands as left by the machines may not resemble the single plant patterns as are now commonly attained by good hand work. This article discusses the yields from sugar beet stands that are believed to be of the type likely to be obtained as mechanization to thin sugar beets is introduced.

The ideal initial stand of sugar beets would, of course, be a stand of vigorous single plants spaced uniformly at exactly the distance that would result in the maximum yield. There is rather general agreement that the fewest possible numbers of seedlings per unit area, that approach this ideal, and these distributed evenly in the row, constitute the best initial stand upon which to base the elimination of hand work in thinning. Sheared seed and improvement in planter design represent the steps now taken in this direction.

Since the greatest efficiency of any modification of conventional hand thinning probably depends on thin initial stands, the use of the lowest seeding rate consistent with local conditions is indicated. When minimum seeding rates are used there will always be the hazard of more or less serious reductions of stand by unforeseen conditions. A very thin stand may produce a profitable crop, even if it is smaller and less profitable than the maximum crop which might have been produced by a good stand or by intensive hand culture methods, since savings in labor may compensate for much of the reduction in yield.

Plants growing in close proximity compete with each other for light, water, and plant nutrients. Experiments have indicated that when sugar beet plants were spaced at as great a distance as 40 by 40 inches this competition was eliminated. There was also a marked reduction in yield per acre from these 40 by 40 inch stands in comparison with stands spaced 10 by 20 inches. If any two men interested in the growing of sugar beets—let them be farmers, sugar company,

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[1]Associate Agronomist, Division of Sugar Plant Investigations, Bureau of Plant Industry, Soils, and Agricultural Engineering, U. S. Department of Agriculture. Paper No. 206, Sci. Jour. Series. Colo Agr. Expt. Sta.

or scientists—were chosen at random, it is probable that their opinions would differ as to the exact spacing of sugar beet plants from which maximum acre yields are obtained. However, there is general agreement that uniformity of spacing is essential for maximum yield. A large proportion of the sugar beet crop of northern Colorado and much of the crop in other regions is grown in rows spaced 20 inches apart and, as a working standard, a stand of 100 beets per 100 feet of row is generally accepted as a full stand. Consequently, for the purposes of this discussion, a full stand of sugar beets is defined as 100 plants per 100 feet of row, the rows being 20 inches apart, and a standard population is defined as approximately 26,000 plants per acre.

Experiments at Fort Collins, Colo.,[2] have given information on the effects of reduced stands on the yield of sugar beets, and the results of these experiments over a number of years, including 1943, have been summarized (*1*).[3] Briefly, these experiments indicated that yields of timely planted sugar beets with stands reduced to 70, 50, and 30 plants per 100 feet of row were approximately nine-tenths, three-fourths, and two-thirds, respectively, of a full crop, i. e. the crop of a full stand of 100 plants per 100 feet of row. Also a 70-percent stand of 12-inch spaced plants was compared with a 100-percent stand of plants with uniform 16-inch spacing, both stands having populations of approximately 18,600 plants per acre. In this comparison the uniform stand outyielded the non-uniform stand by slightly more than 0.6 tons of roots per acre, this difference being probably significant. In all these tests the stands were obtained by hand thinning and the thinned stands were checked for the quality of the work. Thus these stands consisted of single plants with practically no two-plant or multiple-plant hills.

It is obvious that the elimination of conventional hand thinning will result in thinned stands of sugar beets with less uniform distribution of the plant population than could have been obtained by good hand work. The thinned stands of non-hand-thinned sugar beets will consist of one-plant, 2-plant, and multiple-plant hills and skips. The proportions of these types of hills and the uniformity of their distribution will depend upon the number and distribution of the seedlings in the initial stand and the quality of the work done. The average population will be greater or less than the standard population of 26,000 plants per acre.

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[2]Agronomic investigations of the Division of Sugar Plant Investigations at Fort Collins, Colo., are cooperative with the Agronomy Section of the Colorado Agricultural Experiment Station and are conducted on the Agronomy Farm of the latter agency.

[3]Italic numbers in parentheses refer to literature cited.

Materials and Methods

The soil on which these rate of planting experiments and population studies were conducted was Fort Collins loam, light textured phase, and the general level of fertility was fairly high. Spring wheat preceded the beet crop. The wheat stubble received about 10 loads per acre of manure and was fall plowed. In both years the planting of the experiments was delayed by adverse weather in April, the planting dates being May 15, 1944, and May 8-10, 1945.

The weather and field conditions which affected germination of sugar beet seed were probably represetnative of the extremes which might occur in growers fields over a period of several years. These conditions were very unfavorable in 1944 and extremely favorable in 1945. Much of the seed planted in 1944 did not germinate until after a heavy rain and hail storm on May 24 and final initial stands were very poor. Also in this year early emerging weeds were a source of plant competition until after the sugar beets were thinned the latter part of June. It was estimated that the initial stand at the time of thinning represented not to exceed 30 percent of the potential germination of the seed planted in 1944. In contrast, soil and weather conditions in 1945 were very favorable for prompt and vigorous germination of sugar beet seed as shown by the results of an emergence study in which 1,000 seed pieces each of a number of seed lots were planted on May 12. Included in the emergence study were the four kinds of seed used in planting the rate of seeding experiment. Laboratory germinations and field emergence of these four lots of seed were as follows:

1. Whole seed; laboratory germination 156 sprouts and field emergence 154.6 plants per 100 seed pieces.

2. Sheared seed; laboratory germination 112.75 sprouts and field emergence 107.6 plants per 100 seed pieces.

3. Pelleted seed; laboratory germination 53.25 sprouts and field emergence 67.6 plants per 100 pieces.

4. Graded whole seed; laboratory germination 163.25 sprouts and field emergence 153.8 plants per 100 seed pieces.

It was estimated that field emergence from the sugar beet seed planted in the 1945 experiments was in general at a rate in excess of 90 percent of the potential germination of the seed lots used. The initial stands were comparable to the best stands which growers can expect from similar seeding rates under the most favorable conditions in any year. The emergence of early weeds in the 1945 plantings was negligible.

The rate of seeding tests and the population study each consisted of six randomized replications of the treatments with plots eight rows in width and 60 feet in length. The four inside rows of each plot were harvested for yield determinations and two 20-beet samples were taken from each plot for analysis to determine the percentage of sucrose in the beets. In 1945 the data obtained for sucrose content of the roots were erratic and the standard errors applicable to these values were unusually high. It is possible that for plots as large as these were and with beets varying considerably in individual size, as these beets did vary, the standard sampling technique was inadequate. For this reason it is probable that the best measure of yield from the treatments in these tests is the yield of roots rather than the indicated yield of gross sugar.

For the comparison of 20-inch with 40-inch rows in 1945 there were four randomized replications of the treatments with plots 120 feet in length and of sufficient width to permit the harvest of four of the 20-inch rows or two of the 40-inch rows after discarding border rows which might have been affected by competition with the adjacent plot.

The whole area used for the populations study was planted with one of the newer planters, sheared seed being planted at a very heavy rate of seeding on May 8. This test was blocked with long-handled hoe on June 18 and 19. Near perfect stands of blocks, most of which contained two or more plants, were obtained. Final thinning was on June 22, 23, and 25 by two-man teams. One of the men read the chart of the stand, as previously determined by the drawing of random numbers, and the other reduced the blocked hills to the charted stand for each of the plots. The thinned stands obtained on all plots of this test very closely approximated the stands as planned both as to the distribution of the hills and the total populations of plants.

All treatments in the rate of seeding experiments, except those for which pelleted seed was used, were hand planted with Planet Jr. garden drills. The differences in rate of planting were obtained by using mixtures of dead and untreated seed in appropriate proportions. The dead seed for these mixtures was prepared by a hot water treatment. These seed mixtures were planted at a moderately heavy rate of seeding such that the live seed actually planted approximated the planned rate of planting for each treatment. Distribution of the live seed in the row was quite good as indicated by the distribution of the plants in the initial stands, but probably was not equal in uniformity to the seed distribution by some of the modern seed drills. The attained planting rates were calculated from the weight of seed used in planting each treatment. The numbers of viable seed pieces planted per foot of row were calculated from the weight of seed planted and the laboratory germinations of samples of the seed used.

No drill was available that would handle the pelleted seed without considerable grinding of the pellets or that would space individual pellets at the desired intervals. Therefore the pelleted seed was dropped by hand in furrows opened to a depth of about 1½ inches and covered by drawing the soil back into this furrow. This method of planting was probably not comparable to the work of a drill equipped to handle pelleted seed and, particularly in 1945, germination and early growth of the seedlings from the pellets was not as good as from pellets which had been drill-planted in another experiment.

In both years the very thin initial stands in the rate of seeding experiments were thinned with long-handled hoe and the thicker initial stands were thinned in the conventional way with a short-handled hoe. The time used in thinning each plot was recorded. The initial stands from the lowest rates of seeding were left essentially as they emerged, since very few beet plants were cut out of these stands; only weeds were cut out in the thinning operation. Some plants were cut out in thinning the initial stands from the intermediate rates of planting, the best obtainable stand of hills being left. When the initial stands from the heavier rates of seeding were adequate, they were thinned with short-handled hoe to uniformly spaced single-plant hills.

In 1944, two treatments of the lowest rate of planting were included in the rate of planting experiment, the intention being to thin and weed one at the normal date of thinning and to leave the other without thining or weeding until the normal date of the first hoeing of the crop. However, initial stands were so thin and weedy that both treatments were weeded at the normal thinning date, all available sugar beet plants being left in each. Therefore treatments 5 and 6 of this experiment were essentially duplicates and while given separately in the summary of the test may be averaged for purposes of comparison of the lowest rate of seeding with the heavier rates of seeding in this experiment.

In the 1945 rate of seeding experiment each of the three lower rates of planting were seeded in adjacent duplicate plots in each replication for the purpose of supplementing the stand in one of each pair of these plots by planting a single piece of sheared seed in the blank hills when the plots were thinned. Since near perfect thinned stands were obtained in the plots seeded at the 2-pound rate, this supplemental planting was made on only one of each pair of plots seeded at the 0.5- and 1-pound rates. These supplemental plantings failed and therefore treatments 2 and 2a, 3 and 3a, and 4 and 4a, as given in the general summary of this experiment, were essentially duplications of the 0.5, 1- and 2-pound seeding rates, respectively, and have

been averaged in each case for comparison of these seeding rates with the other treatments of the experiment.

Much experimental evidence and the experience of growers have both contributed to the adoption of the 20-inch row width when the crop was thinned and harvested by hand. If hand labor is to be replaced with machines it may well be that a re-examination of row widths is in order. It may be found that some machinery, particularly harvesters, will work more efficiently in wider rows. The suggestion that wider rows be used for the sugar beet crop came to the attention of the staff at the Fort Collins station after the 1945 crop had been planted. However, certain parts of the experimental field which had been uniformly planted at a rate of approximately 2 pounds of sheared seed per acre were available for a perliminary comparison of 20-inch and 40-inch row widths. The 40-inch row width was obtained by cutting out every other one of the 20-inch rows for the 40-inch row plots.

Further details of the treatments used and the stands obtained will be given in the discussions of these experiments.

Population Study, 1945

Low planting rates, machine thinning, or any other method or combination of methods by which conventional hand thinning of the sugar beet crop is eliminated are certain to result in thinned stands which are more or less non-uniform in distribution. This population study was designed for the purpose of gaining information on the probable yields of sugar beets from such non-uniform stands. It seemed reasonable to believe that machine thinning of suitable initial stands could attain a proportion of 75 percent single plant hills in the thinned stand and that most of the other 25 percent of the hills would be doubles. Therefore the proportions of 75 percent singles, 21.5 percent doubles, and 3.5 percent multiples 3- and 4-plant hills) were adopted as the basis for the stands in this experiment. A treatment with a full stand and standard population of 100 single-plant hills per 100 feet of row was added as the check. The full experiment consisted of 10 treatments as follows: Treatment 1; the check. Treatments 2, 3, 4, 6, 8, 9, and 10; stands of 120, 100, 80, 70, 60, 50 and 40 hills per 100 feet of row, respectively,with 75 percent single-plant hills in each case. Treatment 5; a stand of 70 hills per 100 feet of row with 85 percent of the hills single plants. Treatment 7; a stand of 70 hills per 100 feet of row with only 65 percent of the hills single plants. Distribution in each plot of the varying kinds of hills—1-plant, 2-plant, 3-plant, 4-plant or blank, was at random as determined by the drawing of random numbers for every plot in the test. A summary of this experiment is presented in table 1.

Table 1.—Stands, acre yields of roots, sucrose percentage, and gross sugar production as obtained in sugar beet population study. The number of hills and plants per 100 feet of row as expected, as attained at thinning time, and as harvested are given. Eight row plots, 60 feet long, with rows 20 inches apart. Fort Collins, Colo., 1945. (Data given as 6-plot averages).

Treatment			Stands per 100 fet of row								
			Expected		Actual thinned						
No.	Hills per 100 feet of row	1-plant hills (percentage)	Hills	Plants	Hills	Plants	No. of roots harvested	No. of plants lost*	Acre yield of roots (Tons)	Sucrose per centage (Percent)	Acre yield gross sugar (Pounds)
1.	100	100	100	100.0	101.7	101.7	100.8	0.9	15.50	14.08	4,362
2.	120	75	120	154.0	117.1	154.8	142.9	11.9	15.01	14.30	4,291
3.	100	75	100	128.5	100.3	129.1	124.4	4.7	15.52	14.22	4,402
4.	80	75	80	103.1	79.5	102.3	99.2	3.1	14.51	13.48	3,913
5.	70	85	70	82.3	70.8	83.5	81.5	2.0	14.39	14.15	4,075
6.	70	75	70	90.2	69.8	89.9	87.9	2.0	13.78	13.09	3,609
7.	70	65	70	98.3	70.2	99.0	93.3	5.7	13.96	13.09	3,656
8.	60	75	60	77.1	60.1	77.4	74.5	2.9	13.25	13.02	3,456
9.	50	75	50	64.4	50.6	65.1	63.2	1.9	12.24	12.72	3,110
10.	40	75	40	51.0	41.1	52.8	52.0	0.8	11.90	12.49	2,974
	General mean of test								14.00	13.46	3,785
	F value								20.33**	5.00**	23.05**
	2.014 x the S. E. of a Diff. (odds of 19:1)								0.79 T.	0.81%	302 lb.
	2.690 x the S. E. of a Diff. (odds of 99:1)								1.06 T.	1.08%	404 lb.
	S. E. of M. in percent of general mean								1.99%	2.12%	2.80%

*Since actual loss of plants from thinning to harvest by death due to disease or accident was negligible, the values given in this column approximate the number of plants per 100 feet of row which failed to produce roots of marketable size, approximately 1 inch in diameter at the crown.

Discussion

The acre yields from this test were not high but were very good for May 8 planting on this farm. In general, equal stands of hills produced similar yields of roots. The yields from the two treatments with full stands of hills were almost identical though, treatment 3 had one-fourth more plant population than treatment 1. When stands were reduced to 70 percent of a full stand of hills, but with populations of 83.5, 90, and 99 percent, respectively, of a standard population, the yields of roots did not vary significantly.

Treatment 2 had 120 percent of a full stand of hills and approximately 150 percent of a standard population of plants. The yield of roots from this treatment was one-half ton per acre less than the yield of either of the treatments having full stands of hills. This difference is probably not significant, but does indicate that under the conditions of this experiment a full stand of 100 hills per 100 feet of row was sufficient to produce maximum yields.

It is possible to compare some of the treatments in the 1945 experiment with the yields of similar stands of single-plant hills in experiments conducted at this station in former years. The basis of comparison is the yields of the various stands expressed as percent of the full crop obtained from a full stand of 100 single-plant hills per 100 feet of row (the check treatment that was common to all the experiments). These comparisons are presented in table 2.

The average yield of roots from the 70-percent stands of single-plant hills was 96 percent of the yield of roots from full stands in the first series of experiments (1937-1939) and 92 percent of the yield from the full stands in the second series (1941-1943). In the 1945 experiment the three treatments with 70-percent stands of hills with from 14 to 25 percent additional population, present as double- and multiple-plant hills, produced an average yield of roots that was 90.6 percent of the yield from the comparable full stand of single-plant hills. In 1937-1939 the average yield of roots from the 40-percent stands of single-plant hills was 78 percent of a full crop, while in the 1945 experiment the yield from the 40-percent stand of hills, with 25 percent additional population, was 76.8 percent of a full crop. In 1941-1943 the 50-percent stands of single-plant hills produced 80.3 percent of a full crop of roots and in 1945 the 50-percent stand of hills, with its 25 percent of additional population, produced 79 percent of a full crop.

In all these experiments the percentage of sucrose in the roots was lower as stands were reduced. There was no conclusive evidence from the 1945 experiment that the quality of the crop from reduced

Table 2.—Acre yields and sucrose percentage of different sugar beet stands expressed as percentage of a full crop; i. e. the yields and sucrose percentage obtained from comparable stands of 100 single-plant hills per 100 feet of row. Fort Collins, Colo., 1937-1945.

Hills per 100 feet of row	Percent 1-plant hills	Acre yields in percentage of acre yields of 100 single plants per 100 fet of row		Sucrose Percentage
		Roots	Gross sugar	
(No.)	(Percentage)	(Percentage)	(Percentage)	(Percentage)
1937-1939 (Data given as average of three 6-plot averages)				
100	100	100.00	100.00	100.00
70	100	96.13	96.42	99.65
40	100	78.07	76.35	98.23
1941-1943 (Data given as average of three 5-plot averages)				
100	100	100.00	100.00	100.00
70	100	92.04	89.63	97.13
50	100	80.29	71.72	94.41
30	100	64.03	57.46	89.78
1937-1939 and 1941-1943 (Data given as 6-year average of averages)				
100	100	100.00	100.00	100.00
70	100	94.22	93.25	98.77
1945 Population Study (Data given as 6-plot averages)				
100	100	100.00	100.00	100.00
120	75	96.84	98.37	101.56
100	75	100.13	100.92	100.99
80	75	93.61	89.71	95.74
70	85	92.84	93.42	100.50*
70	75	88.90	82.74	92.97
70	65	90.06	83.81	92.97
60	75	85.48	79.23	92.47
50	75	78.97	71.30	90.34
40	75	76.77	68.18	88.71
(Average of three 70-hill stands)		90.58	86.66	95.47

*This value is not in agreement with expectancy or other values obtained and may or may not be confirmed when additional data are obtained.

stands of hills was improved by the additional population in two-plant and mulitiple-plant hills.

Summary of Populations Study

Under the conditions of this experiment at Fort Collins, Colo.. in 1945 the highest yields of sugar beets were obtained from full stands of 100 hills per 100 feet of row. There was no difference in the yields from a full stand of single-plant hills and a full stand with 75 percent of the hills containing single plants and 25 percent containing two or more plants per hill; the 25 percent additional population had no effect on yield.

When the number of hills was increased to 120 percent of a full stand with a corresponding increase to 150 percent of a standard population of plants, there was a small but non-significant reduction in yield. The evidence from this one test indicates that, with uniform distribution of hills, populations moderately in excess of the optimum of about 26,000 plants per acre will produce approximately a full crop of sugar beets.

When the stands of hills were reduced to 80, 70, 60, 50, and 40 percent of a full stand, there were associated reductions in yield. The yields from these reduced stands of hills, each with additional plant population in the two-plant and multiple-plant hills, were of approximately the same order as the yields from similar stands of single plant hills in previous experiments.

The evidence from this experiment strongly supports the conclusion that the yield of sugar beets is determined by the number and distribution of the hills in the thinned stand. Additional plant population due to the presence of two-plant and multiple-plant hills in the thinned stand of sugar beets had little if any effect on yields.

Rate of Seeding Experiment, 1944 and 1945

Summaries of the 1944 and 1945 rate of seeding experiments are presented in tables 3 and 4, respectively. Because of the extreme differences in the stands obtained in these two experiments, attributable to soil and weather conditions affecting germination of beet seed in the 2 years, data from the experiments must be considered separately. However, for convenience, details of the stands obtained and the yields of roots from these experiments are brought together in table 5.

Under the adverse conditions for germination of sugar beet seed in 1944, the stands from the low rates of 0.61, 0.73 and 1.16 pounds of sheared seed per acre were so poor that abandonment of the crop would probably have been justified. When 2.72 pounds of sheared seed were planted, 55 percent of a full stand of hills was saved, and from the 4.50 pounds per acre planting 67.6 percent of a full stand of hills was saved. It is evident that under these adverse conditions a seeding rate of at least 5 pounds per acre of good quality sheared seed would have been necessary to assure even a fairly adequate thinned stand.

Yields of roots from this experiment were considerably below normal yields for the district and somewhat lower than would be expected from late May planting on this farm. However, some of the relative yields from the different seeding rates are of interest. In this experiment the 1.16, 2.72, and 4.50 pound seeding rates produced

Table 3.—Seeding rates, stands obtained, acre yields, and percentage sucrose of sugar beets planted at different rates of seeding. Fort Collins, Colo., 1944. (Data given as 6-plot averages).

Treatment	Planting rate		Stands*				Acre yields		
				Thinned		Harvested			
	Seed per acre (Pounds)	Viable seed pieces per foot of row	Initial	Hills	Plants	Roots	Roots (Tons)	Gross sugar (Pounds)	Sucrose (percentage)
5. Sheared; ½ pound	0.73	0.90	2.7	20.4	25.1	25.1	5.94	1,731	14.48
6. Sheared; ½ pound	0.61	0.75	1.6	14.2	16.9	16.9	4.73	1,330	13.96
7. Sheared; 1 pound	1.16	1.43	3.4	25.3	32.4	32.4	6.76	1,970	14.48
8. Sheared; 2 pounds	2.72	3.35	6.7	55.1	68.8	66.7	8.67	2,728	15.72
9. Sheared; 4 pounds	4.50	5.55	10.9	67.6	80.6	79.8	9.96	3,207	16.12
10. Sheared: heavy	7.36	9.07	22.0	.... ..	94.5	92.3	10.94	3,671	16.77
11. Whole; light	5.12	4.15	15.8	82.5	92.3	89.6	10.67	3,539	16.59
12. Whole; heavy	12.80	10.37	42.7	.... ..	102.8	99.9	10.74	3,606	16.79
General mean							8.75	2,803	15.76
F value							20.69**	27.88**	40.89**
2 x the S. E. of a Diff. (odds of 19:1)							1.37 T.	453 lb.	0.47%
S. E. of M. in percent of general mean							5.53%	5.71%	1.04%

*Initial stand given as plant-containing inches per 100 inches of row.
Thinned and harvested stands given as hills, plants, or roots per 100 feet of row.

Table 4.—Seeding rates, stands obtained, acre yields, and percentage sucrose of sugar beets planted at different rates of seeding. Fort Collins, Colo., 1945. (Data given as 6-plot averages).

Treatment	Planting rate		Stands*				Acre yields		
				Thinned		Harvested			
	Seed per acre (Pounds)	Viable seed pieces per feet of row	Initial	Hills	Plants	Roots	Roots (Tons)	Gross sugar (Pounds)	Sucrose percentage
2. Sheared; ½ pound	0.53	0.87	5.0	46.2	80.9	71.1	11.59	3,106	13.39
2o. Sheared; ½ pound	0.53	0.87	5.0	49.4	89.9	78.7	11.82	3,224	13.59
3. Sheared; 1 pound	1.10	1.61	10.4	73.6	130.2	116.4	13.53	4,010	14.82
3a. Sheared; 1 pound	1.10	1.61	10.4	73.9	131.2	115.2	13.42	3,884	14.46
4. Sheared; 2 pounds	2.40	3.50	19.8	97.8	100.1	98.8	15.02	4,307	14.36
4a. Sheared; 2 pounds	2.40	3.50	20.3	97.5	99.6	97.1	14.93	4,448	14.88
5. Sheared; 3 pounds	3.59	4.73	27.6	....	101.7	98.8	15.10	4,315	14.32
6. Sheared; heavy	5.72	6.84	37.1	....	100.0	99.8	15.22	4,334	14.24
7. Whole; heavy	14.79	12.84	59.8	....	96.0	94.5	14.53	4,086	14.09
8. Whole; graded†	4.26	5.24	28.6	....	99.7	99.0	14.27	4,207	14.72
General mean							13.77	3.924	14.28
F value							21.24**	16.90**	3.17**
2.008 x the S. E. of a Diff. (odds of 19:1)							0.86 T.	328 lb.	0.75%
S. E. of M. in percent of general mean							2.19%	2.93%	1.84%

*Initial stands given as plant-containing inches per 100 inches of row.
Thinned and harvested stands given as hills, plants, or roots per 100 feet of row.

†Whole seed as issued was regraded in a Clipper mill. The seed saved went through a 12/64 screen and over a 7/64 screen and was subjected to moderately heavy air blast. Germination tests indicate that average germination of the seed balls was raised 6 percent by this treatment and that the percentage of seed balls producing one or two sprouts was raised from 69.75 to 79.25 percent.

Table 5.—Stands and acre yields of roots of sugar beets planted at comparable rates of seeding in 1944 and 1945, Fort Collins, Colo. (Data given as 6-plot averages).

Seed	Seeding rate		Stands*						Harvested		Acre yield	
			Thinned									
			Initial		Hills		Plants		Roots		Roots (tons)	
	1944	1945										
	(Pounds per A.)		1944	1945	1944	1945	1944	1945	1944	1945	1944	1945
Sheared	0.67†	0.53‡	2.2	5.0	17.3	47.8	21.0	85.4	21.0	74.9	5.34	11.70
Sheared	1.16	1.10‡	3.4	10.4	25.3	73.8	32.4	130.7	32.4	115.8	6.76	13.48
Sheared	2.72	2.40‡	6.7	20.0	55.1	97.7	68.8	99.9	66.7	98.0	8.67	14.98
Sheared	4.50	3.59	10.9	27.6	67.6	.... ..	80.6	101.7	79.8	98.8	9.96	15.10
Sheared	7.36	5.72	22.0	37.1	.... ..	.... ..	94.5	100.0	92.3	99.8	10.94	15.22
Whole	5.12	4.26	15.8	28.6	82.5	.... ..	92.3	99.7	89.6	99.0	10.67	14.27
Whole	12.80	14.70	42.7	59.8	.... ..	.... ..	102.8	96.0	99.9	94.5	10.74	14.53
									Difference required for signif. (19:1)		1.37	0.86

*Initial stands given as plant-containing inches per 100 inches of row.
Thinned and harvested stands given as hills, plants, or roots per 100 feet of row.
†1944 data are averages of averages of two plantings, one at 0.73 and the other at 0.61 pounds of seed per acre.
‡1945 data are given as 12-plot averages, since these treatments were planted in duplicate.
Where no data are recorded for stand of hills, the thinned stands consisted of approximately all single-plant hills.

thinned stands of 25.3, 55.1, and 67.6 percent, respectively, of full stands of hills. These stands contained 32.4, 66.7, and 80.6 percent, resepectively, of standard populations. The yields of roots from these three seeding rates were 61.8, 79.3, and 91.0 percent, respectively, of the yield obtained from the approximately full stand obtained from the 7.36 pound seeding rate. Proportionally these yields were in fairly good agreement with the yields obtained from the 30, 50, and 70 percent stands of single-plant hills in the experiments conducted from 1937 to 1943. It is evident that the 20 to 25 percent additional plant population present in these stands as two-plant and multiple-plant hills did not contribute proportional increases to the yields of roots.

Under the extremely favorable conditions of 1945, the initial stands in the rate of seeding experiment varied from 5.0 plant-containing inches per 100 inches of row when 0.53 pounds of sheared seed per acre had been planted to an initial stand of 59.8 from the heavy seeding of whole seed. The 0.53 and 1.10 pound seeding rates were thinned with long-handled hoe, and 47.8 and 73.8 percent of full stands of hills, respectively, were obtained. These stands contained 85.4 and 130.7 percent, respectively, of standard populations. All the other rates of seeding in this experiment were hand thinned in the conventional manner with the short-handled hoe, and approximately full stands of well distributed single plant hills were obtained.

It was observed that the seedlings in the thick initial stands from the heavy seeding of whole seed were smaller and growing less vigorously when thinned. This difference was somewhat evident for about 3 weeks following thinning, and the slightly lower yield of this treatment may be attributable to the slower early rate of growth of these plants.

In thinning the plots planted at the 0.53 pound seeding rate, only weeds were cut out, all beet plants being left as they emerged. Only a few beet plants were cut from the thickest parts of the initial stands from the 1.10 pounds seeding rate. In the thinned stands of these two treatments there were approximately 43, 42, and 15 percent of one-plant, two-plant, and multiple-plant hills, respectively.

The yields of sugar beets obtained from this experiment were not high but were very good for May 10 planting on this farm. As would be expected, the yields of roots from the practically equal and uniformly spaced stands of the three higher rates of seeding sheared seed were approximately the same. Yields from the similar stands obtained from the light seeding of graded whole seed and the heavy seeding of normal whole seed were slightly lower, but the differences were of doubtful significance. The average yield of roots from all

treatments with full stands was 14.84 tons per acre. Less than full stands of hills were obtained from each of the lower seeding rates of sheared seed, and the yields of roots were correspondingly lower. The yields of roots from the 0.53 and 1.10 pound seeding rates were, respectively, 11.70 and 13.48 tons per acre. These yields are of particular interest since they appear to have been determined by the number and distribution of the hills in the thinned stand.

The thinned stand from the 0.53 pound seeding rate consisted of nearly half a full stand of hills containing 85 percent of a standard population. However, the distribution of this population was poor since only 41 percent of the hills were singles while 40 percent were doubles and 16 percent were multiples (three to seven plants). Distribution of the hills in the row was also poor since blanks in excess of 3 feet in length were not uncommon. The thinned stand obtained from the 1.10 pound seeding rate consisted of slightly less than three-fourths of a full stand of hills containing 130 percent of a standard population. This was essentially a population which was more than adequate, but it was poorly distributed since 42 percent of the hills were singles, 43 percent doubles, and 15 percent multiples. Distribution of the hills in the row was much better than in the case of the 0.53 pound seeding rate, but there were appreciable numbers of blank spaces of moderate length in all rows. Acre yields and sucrose percentages of the crops from the two low rates of seeding are compared with the average acre yield and sucrose percentage of the crops from the higher rates of seeding, having full stands and standard populations, in the 1945 rate of seeding experiment and with the percentages of a full crop obtained from similar stands of single-plant hills in older experiments (1937-1943) in table 6.

In the older experiments with single-plant hills it was found that, on the average, a half stand would produce about three-fourths of a full crop and that a 70-percent stand would produce about nine-tenths of a full crop. Under the conditions of the 1945 rate of seeding experiment, 47.8 percent of a full stand of hills containing 85.4 percent of a standard population produced 78.8 percent of a full crop of roots, and a 73.9 percent stand of hills containing 130.7 percent of a standard population produced 90.8 percent of a full crop. These yields are in striking agreement with the expectancies if it can be assumed that yield of sugar beets is primarily determined by the number of hills in the thinned stands. Apparently the additional population of plants, present in two-plant and multiple-plant hills, in the stands obtained from the low seeding rates in the 1945 experiment had little if any effect on the yields.

Table 6—Stands, acre yields, and sucrose percentage of the sugar beet crop from two low rates of seeding in comparison with the average stand, acre yield, and sucrose percentage of the five higher rates of seeding having full stands of single-plant hills and with the percentage of a full crop obtained from similar stands of single-plant hills in other experiments. Rate of seeding experiment, 1945, and population studies, 1937-1943, Fort Collins, Colo.

Acre seeding rate (Pounds)	Stand		Acre yields				Sucrose percentage	
			Roots		Gross sugar			
	hills	plants	(Tons)	In percent of full crop	(Pounds)	In percent of full crop	(Percentage)	In percent of full crop
1945								
2.40 up*	98.9	99.5	14.84	100.00	4,283	100.00	14.44	100.00
1.10†	73.8	130.7	13.48	90.84	3,947	92.16	14.64	101.39
0.53†	47.8	85.4	11.70	78.84	3,165	73.90	13.49	93.42
1937-39‡	70.0	70.0		96.13		96.42		99.65
1941-43‡	70.0	70.0		92.04		89.63		97.13
1941-43‡	50.0	50.0		80.29		71.72		94.41

*1-year average of six 6-plot averages.

†1-year average of two 6-plot averages.

‡3-year averages.

Pelleted Sugar Beet Seed

Pelleted sugar beet seed as obtained from the Farmers and Manufacturers Beet Sugar Association was included at two rates of planting in the 1944 rate of planting experiment and at one rate of planting in the 1945 experiment. In 1944, emergence from the pelleted seed following a soaking rain on May 24, while rather poor as to the total seedlings which emerged, was relatively slightly better than emergence from sheared or whole seed planted in this experiment. In 1944 the seedlings from the pelleted seed were aparpently as vigorous as seedlings from other sugar beet seed. Under the favorable conditions for germination in 1945, the total number of seedlings emerging from pelleted seed exceeded the total germination recorded from pellets in the laboratory. However, in 1945 the seedlings from the pellets were slow in emerging and many were very weak and made slow early growth. This slow emergence and weakness of the plants from the pellets are believed to be due to hand planting of the pellets in an open furrow, but the exact cause is not known.

The stands and yield from pelleted sugar beet seed and from comparable plantings of whole and sheared seed are presented in table 7.

Table 7.—Seeding rates, stands, and acre yields of roots of sugar beets grown from pelleted, sheared, and whole seed, Fort Collins, Colo., 1944-1945. (Data given as 6-plot averages.

Seed	Seeding rate 1944 (Pounds per A.)	Seeding rate 1945 (Pounds per A.)	Stands* Initial 1944	Stands* Initial 1945	Stands* Thinned Hills 1944	Stands* Thinned Hills 1945	Stands* Thinned Plants 1944	Stands* Thinned Plants 1945	Stands* Harvested Roots 1944	Stands* Harvested Roots 1945	Acre yield Roots (tons) 1944	Acre yield Roots (tons) 1945
Pellets	10″ sp.	4″ sp.	3.3	12.0	27.3	99.1	30.8	123.6	30.6	109.1	6.30	12.03
Pellets	6.30†	.... ..	25.1	.... ..	.... ..	.... ..	99.1	.... ..	96.4	.... ..	10.09	.... ..
Sheared	0.67‡	0.53	2.2	5.0	17.3	47.8	21.0	85.4	21.0	74.9	5.34	11.70
Sheared	1.16	1.10§	3.4	10.4	25.3	73.8	32.4	130.7	32.4	115.8	6.76	13.48
Sheared	8.29	5.72	32.7	37.1	.... ..	.... ..	102.5	100.0	100.8	99.8	9.88	15.22
Whole	16.87	14.79	62.3	59.8	.... ..	.... ..	103.2	96.0	101.0	94.5	10.31	14.53
									Difference required for significance (odds of 19:1)		1.37	0.86

*Initial stands given as plant-containing inches per 100 inches of row.
Thinned and harvested stands given as hills, plants, or roots per 100 fete of row.
†Approximate weight of sheared seed pieces in the pellets planted.
‡1944 data are averages of two plantings, one at 0.73 and the other at 0.61 pounds per acre.
§1945 data given as average of duplicate plantings at these rates.
Where no data are recorded for stands of hills, the thinned stands consisted of approximately all single plants.

In 1944 the yields from pelleted seed were similar to the yields from comparable stands of sheared or whole seed. In 1945 the stands obtained by long-handled hoe thinning, which consisted of cutting out weeds and some of the weakest plants where there had been emergence from four or more consecutively dropped pellets, were not strictly comparable to the stands obtained from any of the sheared or whole seed plantings. The thinned stand from the pellets was similar to the thinned stand obtained from the 1.10 pound planting of sheared seed in that the distribution of the hills in the row was not uniform and the total population of plants exceeded a standard population. Since the low yields from the pellets in 1945 may be attributable to the abnormal conditions under which the pelleted seed was planted, little significance can be given to any comparisons with the yields from sheared or whole seed in the experiment.

These limited trials with pelleted sugar beet seed indicate that there was better emergence of seedlings in the field from such seed than was indicated as probable by laboratory tests of its germination. It is also probable that the coatings used in pelleting this seed cannot be considered as entirely satisfactory.

Supplementary Planting

It has been suggested that sugar-beet stands could be improved by the planting of a single piece of sheared sugar beet seed in each blank hill at the time the crop is thinned. In 1945 duplicate adjacent plots were planted at each of the three lower rates of planting in the rate of seeding experiment. One of each pair was to have supplemental planting and the other to be left with the best stand obtainable from the original planting. Since a full stand was obtained from the original planting at 2.40 pounds of seed per acre, only the plots planted at 0.53 and 1.10 pounds per acre were used for the test of supplemental planting. The day that thinning of this test was completed, one of each pair of the plots planted at the two lower rates received a supplemental planting of a single piece of sheared seed in every blank hill. Emergence of seedlings from these seed pieces was prompt and it was estimated that plants emerged from more than three-fourths of them. However, when the experiment was cultivated and ditched for the first irrigation, in early July, a large proportion of these small seedlings were covered by dirt thrown on the rows by the cultivator shovels. A few of these plants persisted until harvest, but none were found at harvest which had produced a root of marketable size. In this experiment supplemental planting was a failure and it is doubtful if the method will be of any practical value as a means of repairing a thin stand of sugar beets.

Wide Rows

The initial stand of sugar beet plants on the area used for this experiment was too thin to obtain uniform distribution of single plants spaced less than about 8 or 9 inches apart in the rows. Therefore the experiment as conducted consisted of three treatments: (1) Full stand and standard population in 20-inch rows; (2) 12-inch spacing in 40-inch rows; and (3) 8-inch spacing in 40-inch rows. The populations of these treatments approximated 26,000, 13,000 and 20,000 plants per acre, respectively. Therefore these three treatments may be regarded as: (1) A full stand with a standard population; (2) a 50 percent stand containing half a standard population; and (3) a 50 percent stand containing three-fourths of a standard population.

Harvested stands, acre yields, and sucrose percentages of the sugar beet crop from this preliminary experiment with wide rows at Fort Collins are presented in table 8.

Table 8.—Harvested stands, acre yields, and sucrose percentage of sugar beets grown in 20-inch and 40-inch rows, Fort Collins, Colo., 1945. (Data given as 4-plot averages).

Spacing	Roots harvested (No per A.)	Acre yields		Sucrose percentage (Percent)
		Roots (Tons)	Gross sugar (Pounds)	
12″ in 20-inch rows	26,423	16.40	4,740	14.49
12″ in 40-inch rows	13,303	12.80	3,080	12.05
8″ in 40-inch rows	20,295	12.29	3,182	12.94
General mean		13.83	3,668	13.16
F value		55.12**	42.74**	6.15*
2.447 x the S. E. of a Diff.		1.04 T.	493 lb.	1.72%
S. E of the M. in percent of the general mean		2.18%	3.88%	3.78%

Because of the excellent stands obtained and the large size of the plots the general reliability of this experiment was probably very good. The yield of sugar beets spaced 12 inches apart in 40-inch rows, half a standard population, was 3.6 tons of roots and 1,600 pounds of gross sugar per acre less than the yield from the same plant spacing in 20-inch rows; i. e. the yield of a full stand and standard population. Contrary to expectations, increasing the population in the wide rows by spacing the plants 8 inches apart in the row had no effect on the yield of roots but may have slightly improved the quality of the crop. If we assume that in either case, 12-inch or 8-inch spacing, the sugar beet plants fully occupied the wide rows lengthwise of the rows,but that the cutting out of every other one of the 20-inch rows had reduced the total stand to 50 percent of a full stand, the yields of roots from the wide rows very closely approximate the ex-

pected three-fourths of a crop from half a stand. In this preliminary experiment 40-inch rows were too wide for the production of a full crop of sugar beets.

Summary and General Conclusions

If the growing of the sugar beet crop is to be completely mechanized it is probable that much lower rates of seeding must be used than has been customary when the crop was hand thinned. The experiments reported herein indicate that the minimum amounts of seed which will insure reasonably adequate thinned stands of sugar beets will vary between rather wide limits, depending on soil and climatic conditions present at the time of and immediately following the planting of the crop. In these experiments about 5 pounds per acre of good quality sheared seed would have been barely sufficient to produce a reasonably good thinned stand in 1944. Under the very favorable conditions of 1945 nearly perfect thinned stands were obtained from seedlings only slightly in excess of 2 pounds per acre, and approximately three-fourths of a full crop of sugar beets was grown from a seeding of only 0.53 pounds of sheared seed per acre.

Under the conditions of these experiments, maximum yields of sugar beets were obtained from uniformly distributed thinned stands of about 100 single-plant hills per 100 feet of row when the rows were 20 inches apart. A 25 percent increase in plant population, when 25 percent of the hills in a full stand were two-plant and multiple-plant hills, produced yields of roots and sugar which were practically identical with the yields from a full stand of single-plant hills. When plant populations were increased 50 percent by increasing the stand of hills to 120 per 100 feet of row, with one fourth of the hills containing two or more plants per hill, there was a small reduction in yield. However, on the basis of the single test, this reduction in yield was not statistically significant.

In these experiments reductions in the stand of hills below a uniformly distributed stand of about 100 hills per 100 feet of row invariably resulted in a reduction in yield. Stands of hills varying from 40 to 80 percent of a full stand, but which contained two-plant and multiple-plant hills in sufficient numbers to raise the plant populations to from 15 to 35 percent above the populations of similar stands of one-plant hills, produced yields which were about the same proportion of a full crop as the yields from comparable stands of one-plant hills in previous experiments. Under the conditions of the experiment conducted in 1945 the yields from 70 percent stands of hills, of which 15, 25 and 35 percent, respectively, were two-plant and multiple-plant hills, were very similar and of about the same order as the yields to be expected from a 70 percent stand of one-plant hills. The

evidence from these experiments was that yields from stands varying from about 25 to 120 hills per 100 feet of row were determined by the number of hills and that additional plant population contained in two-plant and multiple-plant hills did not increase yields.

There are some indications that the harvesters now available will handle sugar beets from single-plant hills somewhat more efficiently than beets from two-plant and multiple-plant hills. It is also obvious that few sugar beets of marketable size will usually be produced in hills containing more than two or three plants. Therefore the thinned stand of sugar beets, by whatever method it is obtained, should consist of as high a proportion of single-plant hills as can be obtained from the initial stand of seedlings without reducing the total stand of well distributed hills below the maximum number obtainable up to a full stand.

Pelleted seed in limited tests in 1944 and 1945 did not give satisfactory stands.

Supplemental plantings in which sheared seed units were made to fill in gaps in the row did not give roots of marketable size.

Acre-yield of roots and of sugar from sugar beets grown in 40-inch rows with plants spaced either 8 inches or 12 inches apart in the row were significantly below the acre-yields as obtained from sugar beets grown in 20-inch rows with 12-inch spacings.

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Some Aspects of Commercial Scale Sugar Beet Harvesting

AUSTIN ARMER[1]

The agricultural labor shortage in California during the war years was keenly felt by sugar beet growers, particularly during the harvests of 1943 to 1945. Labor demands for spring work were fairly well met, but an acute shortage of harvest labor was encountered.

The demand for harvest mechanization was pressing and was instrumental in accelerating the development and utilization of the Marbeet sugar beet harvester. In 1943 there were used in California 35 Marbeet single-row beet harvesters, and in 1944 the number was increased by 50 two-row machines. Twelve of the two-row harvesters were made available to growers by the Spreckels Sugar Company in 1944. Whereas these 12 machines covered 1,932 acres (an average of 161 acres per machine), this accomplishment was viewed as a large-scale experiment, valuable primarily because of the experience gained with the machine's weaknesses and the problems of field management.

In order to insure a maximum of mechanically harvested acreage in 1945, the Spreckels Sugar Company purchased 25 additional two-row Marbeet harvesters and modernized the 12 machines used in 1944. The 1944 experience proved that harvesters alone do not constitute a functioning harvest organization. Consequently a plan of operation was drawn up and implemented with personnel and equipment. The plan is herewith outlined:

1. The Company will rent Marbeet harvesters to its beet grow-growers for $10 per acre.
2. The grower may apply this rental (less cost of service parts) toward the purchase of the harvester.
3. Contractors equipped with suitable tractors may rent harvesters on the same terms as growers.
4. The Company will maintain the machines in operating condition, and will transport harvesters to and from growers' fields.

The $10 per acre rental figure was calculated to defray only mechanical service cost and amortization over a 2-year period.

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[1]Agricultural Engineer, Spreckels Sugar Company.

Figure 1.—Heavy service trucks were equipped to make major repairs in the field.

Permitting growers to apply their rental against the purchase of harvesters provided an incentive toward eventual ownership of harvesters.

By encouraging contract harvesting, mechanization was provided for growers having small acreages or inadequate tractor equipment.

Mechanical service and transportation of harvesters was an essential Company function. Harvesters operated in areas separated by as much as 370 miles and frequently remote from adequately equipped service shops.

Administrative Organization

The Company's Agricultural Department was the framework upon which the harvesting organization was built.

Field superintendents were responsible for:

1. Assigning harvesters to growers whose tractor equipment and field conditions warranted mechanical harvest.
2. Scheduling harvest dates.
3. Measuring and reporting weekly acreage mechanically harvested.
4. Advising weighmasters at receiving stations to mark scale-beam tickets applying to machine harvested beets.

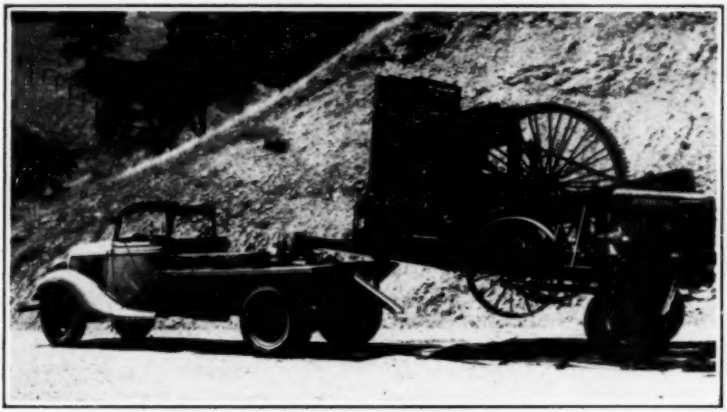

Figure 2.—Harvesters were transported on rubber tired dollies, drawn by trucks designed for harvester towing.

Mechanical Service Organization

Two district harvesting units were established. Each consisted substantially of the following units:

18 two-row Marbeet harvesters.

1 heavy service truck, carrying arc welder, acetylene equipment, hand tools, and complete parts supply (figure 1).

1 light service truck, carrying hand tools and selected parts supply.

2 trucks with rubber tired dollies for transporting harvesters (figure 2).

1 district maintenance shop.

The operating personnel for each harvesting unit included:

1 machinery supervisor.

2 mechanics.

2 truck drivers and mechanics' helpers.

Clerical Organization

Each district agricultural office was charged with the responsibility of:

1. Tabulating weekly acreage, tonnage, sugar percentage, tare, and operating time for each harvester. (A specimen report is shown in figure 3.)
2. Plotting a seasonal performance chart for each machine. (A specimen chart is shown in figure 4.)
3. Preparing a weekly financial report on harvester operation.
4. Charging harvester rentals to growers' accounts.

Harvester Performance

The Company's 1945 mechanical harvest is summarized herewith:

	Spreckels Sugar Company	State of California
Total acres harvested	38,223	90,000
Acres mechanically harvested	10,715	27,000
Percentage of mechanically harvested acreage	28.1 percent	30.0 percent
Average tare of mechanically harvested beets	5.48 percent	
Average tare of all beets harvested	4.80 percent	
Average acreage per two-row Marbeet harvester	281.2	225.

In 1944 the average acreage covered by Company-owned Marbeet harvesters was 161 acres per machine. This performance was analyzed on the basis of three factors: mechanical breakdown, field management, and adverse weather. This analysis is here tabulated and extended to include the predicted and actual acreages for 1945:

	1944 actual	1945 predicted	1945 actual
Mechanical breakdown factor	.61	.80	.92
Field management factor	.70	.80	.70
Adverse weather factor	.65	.85	.78
Overall factor (product of above)	.278	.543	.502
Acres per harvester*	161	305	281

*Obtained by multiplying the theoretical maximum of 560 acres by the overall factor.

It is evident that the field management factor is the greatest deterrent to high load factor, and that emphasis must be placed upon maximum grower utilization, minimum delay in scheduling harvest movements, selection of fields suitable for mechanical harvest, and unintrrupted operation of receiving stations.

It is noteworthy that the harvesters covering the greatest acreage were those operated by contractors rather than by growers. Such contractors, owning their own tractors and renting Company-owned machines, offer the grower a most desirable harvesting system. In all cases the contract cost per ton of beets mechanically harvested was

PRODUCTION BY MARBEET HARVESTERS, WEEK ENDING NOVEMBER 3, 1945 SPRECKELS SUGAR COMPANY, SPRECKELS, CALIF.

District	Field Supt.	Grower	Mach. No.	No. loads	2d net tons	Lbs. dirt	Percent Tare	Percent Sugar	Acres Week	Acres Date	A. hr.	Hrs. oper.	%* oper.	A. to date per mach.
1	W.B.M.	Sig Sanchez	41	10	102	10,090	4.93	17.38	14	110	1.17	12	100	314
1	C.E.C.	M. P. Baliel	48	32	117	28,410	4.29	17.40	8	201	.59	16	100	201
1	H.V.	Chas. Sargenti	49	21	168	11,060	3.65	15.81	8	27	.40	20	100	288.3
1	G.M.	H. E. Bailey	52	5	68	5,370	1.98	18.32	6	199	.60	10	100	205
1	W.B.M.	A. S. Nyland	69	7	80	3,820	4.63	16.10	3	215.7	.50	6	100	215.7
1	J.B.L.	M. G. DaRosa	74	20	105	13,590	4.71	16.76	5	11	.50	10	100	185
1	C.E.C.	Clement & Thayer	84	9	59	15,780	3.10	17.47	16	16	.80	20	100	104
1	G.M.	E. O. Henderson	86	8	80	21,390	6 20	17.20	5	67	.56	9	100	159.6
1	H.V.	Peter Stolich	87	25	238	26,700	5.79	15.06	10	55	.50	20	100	207.1
1	G.M.	Joe Prieto	88	6	65	8,050	4.72	17.68	4	38				
1	G.M.	T. H. Holthouse	88	16	177	25,510	2.89	16.00	9	9	.62	21	100	165
1	R.E.F.	Strobel Bros.	90	20	135	20,730	6.06	16.96	7	12	.35	20	100	171
1	W.B.M.	E. DeWitt	92	7	58	15,260	5.28	16.10	3	96	.50	6	100	306.3
1	H.V.	C. H. Ferrasche	95	28	178	42,900	3.49	15.75	6	24	.40	15	100	276.8
1	G.M.	John Capitanich	96			Not Operated				121				259.6
1	J.B.L.	J. E. Culver	97	79	507	55,670	2.87	18.39	22	89	.73	30	100	206.5
1	W.B.M.	H. Allemand	98	1	14	750	5.40	16.10	3	296	.50	6	100	296
1	W.B.M.	Frassetti Bros.	99	5	40	3,820	4.72	15.52	2	10	.67	3	100	407.7
1	G.M.	D. Martin	100	9	85	7,950	4.59	17.06	1	19	.50	2	100	276.4
1	J.B.L.	N. Forden	101	21	113	10,900	4.00	16.73	14	23	.58	24	100	201
		TOTALS		329	2,449	327,750	4.38		146		.58	250	100	4,506

Remarks: Causes of non-operation, etc.

*As influenced by machine breakdown only. All machines stopped a/c ra in.

Figure 3.—Specimen of weekly harvester production report.

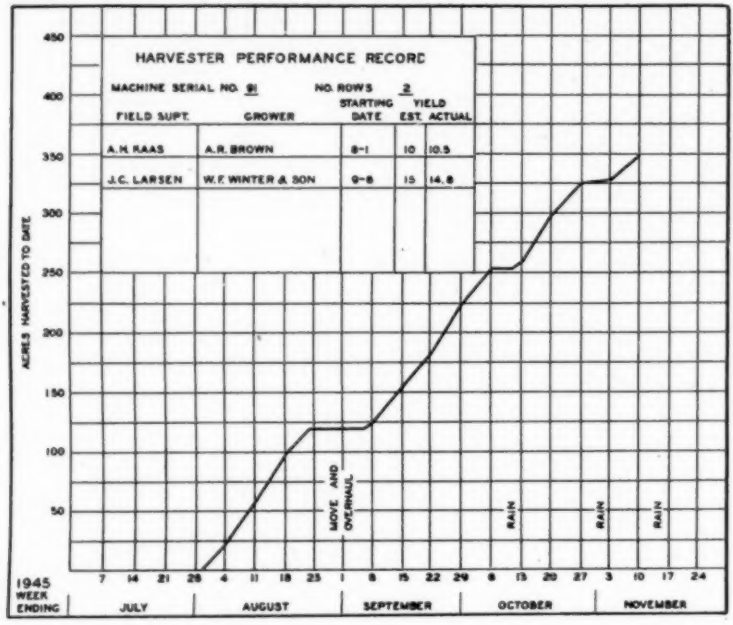

Figure 4.—Specimen of individual harvester performance record.

Figure 5.—Good field management is illustrated by this example of truck scheduling, whereby no harvester time is lost for want of trucks.

less than current hand labor rates. The growers had no cares or responsibilities and welcomed the contract harvester. The contractors' costs were low enough to provide good wages plus a considerable profit.

Of the harvesters rented to growers or contractors in 1945, 40.5 percent were sold to their users, who exercised their option to apply rental toward the purchase price.

Conclusions

The Company's experience to date points out certain well defined trends in the mechanization of the sugar beet harvest. These are:

1. Mechanization is accelerated by the owning and servicing of harvesting machinery by the sugar company.

2. Eventual ownership of harvesters comes about naturally to those growers whose acreage is large enough to provide good harvester load factor.

3. The majority of small-acreage growers will eventually avail themselves of the services of harvesting contractors.

4. The sugar company will own and service a constantly decreasing number of harvesting machines.

Progress in Beet Harvester Development At The University of California, 1945

J. B. Powers[1]

Harvester studies at Davis during the past few years have centered about the development of a single-unit harvester capable of topping the beets, windrowing the tops, lifting and cleaning the roots, and conveying them to a stationary vehicle at the edge of the field. Since the sugar companies are in an excellent position to observe the work of machines in commercial use, less emphasis has been placed on observation and testing of these machines by the University than was the case in the earlier stages of their development.

Certain objectives and standards of performance were agreed upon at the outset of the project which were thought to be representative of what the industry might accept as satisfactory performance in a beet harvester. Some were drawn from sugar company recommendations and others from then current field practices. In the light of present practices some of these objectives appear unreasonably high, but the unsettled state of the beet industry makes revision at this time purely guesswork.

The objectives toward which the Davis staff has been working are:

General

1. All apparatus to be mounted on a standard type wheel tractor for ready maneuverability.

2. Harvest crew to consist of one machine operator and not more than one scavenger.

3. No unusual skill to be required in operation of machinery.

4. All operations to be completed in one transit of machine through the field.

5. Operation to be possible in all ordinary soil types under any field moisture conditions which permit operation of wheel tractor.

6. Machine to be capable of opening its own lands.

Topping

1. Topping to be satisfactory in beets ranging up to 9 inches in height, and in tops of any size.

2. Topping loss under ordinary conditions not to exceed 1.5 percent and top tare not to exceed 3.5 percent.

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[1]Associate Agricultural Engineer, Agric. Experiment Station, Davis, Calif.

3. Tops to be left clean and in acceptable condition for forage or harvesting.

Digging and Lifting

1. Losses after scavenging not to exceed 3 percent by weight.

2. Beets to be delivered free of serious bruising or other injury.

3. Dump screenings not to exceed 5 percent of beet weight except in muddy conditions.

No attempt was made to establish fixed standards of field efficiency, harvesting capacity, or first cost since there were no precedents on which to base them. These three factors are interrelated in the operating cost and would probably vary widely among different systems of harvesting.

Because of the multiplicity of operations to be performed by a single unit, the machine is certain to be complex. Since the design is circumscribed by a large array of requirements, development is certain to be slow. Progress has been consistent but much slower than was thought probable at the outset.

A combination of machine elements has been devised which, with further development, shows promise of satisfying the foregoing requirements. The machine's ultimate cost and fieldworthiness are open questions. A pair of coulters and jointers are used to prepare the row for subsequent operations. A narrow, self-centering, power driven, track-equipped finder rides over the center of each beet and elevates a knife blade to the proper topping level. The severed crowns are grasped by spring-fingered drums which windrow them just inside the tractor wheel.

The roots are loosened by a pair of helical plow points which simultaneously fracture the lower 3 inches of disturbed soil. The remainder of the soil is fractured by a pair of driven coulters operated at such an angle and spacing as just to permit the largest beets to pass between them. The portion of the tap root projecting below the plow points is grasped by a pair of gathering chains, and the larger beets are similarly gripped by overhead chains which operate above the surface of the soil. The soil is thus permitted to fall free as the beets are elevated into a hopper.

The hopper is a long, inclined, conveyor-type bin of 1 ton capacity. It is mounted on the tractor and is equipped with a slow drive for use in filling and a fast drive to discharge the beets into a truck. It thus serves the dual purpose of hopper and elevator.

All working parts are held at a fixed level with respect to the

ground in the beet row with conventional hydraulic lift equipment. Operation is thus independent of field roughness within ordinary limits.

Field Results—1945

Results obtained with the machine during the 1945 harvest season are summarized in table 1. The first four entries were in dry fields; the last two, in wet fields. The third entry shows a total failure in the Clarksburg region in a partial peat soil.

Table 1.—Results obtained with the U. C. Harvester in California fields during 1945. The first four tests were in dry fields and the last two in wet fields.

	Factory data				Test results		
Place	Acres harvested	Net tons harvested	Av. screenings per 5 tons (Pounds)	Av. factory tare (Percent)	Topping loss (Percent)	Top tare (Percent)	Recovery average (Percent)
U. C. over-wintered beets	2.0	50.0	....	....	....	....	88.0
Diener Bros. Harnish Bros., Helm	3.74	43.3	324	....	2.2	2.75	82.8
Olson & Slater Clarksburg	0.74	12.0	....	....	....	....	60 (est.)
Jas. Marshall, Clarksburg	5.19	100.4	348	3.4	....	....	85.5
U. C. 1945 beets	2.4	36.3	620	4.4	....	....	84.8
J. Simmons, Davis	5.3	129.5	870	8.9	....	....	88 (est.)
Total	19.37	371.5					

Observations on Field Trials

Topping.—Topping probably fulfills our original objectives in clean, well-thinned fields, dry or wet. It is appreciably but not seriously affected by a poor thinning job or by weeds under dry field conditions. A combination of wet soil and tough-stalk weeds, however, causes the quality of the work to depreciate to a barely acceptable level.

The tops are left in satisfactory windrows and are not run over

by the machine or any other vehicle. It would be desirable to include apparatus for placing more than one row of tops in a windrow.

Lifting.—The beets are loosened satisfactorily by the plow under all conditions. The recovery of roots by the grasping chains is about 85 percent by weight under most dry ground conditions, and grades to a maximum of 95 percent under optimum wet field conditions. The missed beets are left in plain view on the ground surface, but there are many obstacles in the way of their recovery by hand methods. One man is unable to follow the harvester and load the missed beets directly into the machine. Two men cannot work effectively behind the machine and can keep up to it only when its speed is far below optimum.

When two men are used to windrow the beets, it is necessary that each work a single row since earth is crowded into the harvested rows by subsequent passages of the machine. This, combined with the necessity of handling the beets twice, makes the operation too expensive to be practical.

The cleaning of the beets probably satisfies our original requirements. Dump screenings varied from 3 percent under favorable conditions to 12 percent under muddy conditions. Whereas it would be desirable to lower the latter figure, it is already well below that for beets harvested under similar conditions by hand methods.

Hopper.—The hopper-elevator system of storage of the harvested roots has proved successful. It permits operation in fields far too muddy for successful truck operation, and it has proved a great boon in opening lands. Its greater maneuverability as compared with a trailed hopper permits operation in small fields with narrow headlands. It does, however, impose a severe static load on the tractor. No difficulty was experienced from this source during the year's work, but it may reasonably be expected to shorten tire life considerably. Whether or not its advantages are sufficient to offset this disadvantage can be determined only by further field experience.

General.—The maneuverability of the machine in turning or backing is good. In this respect it is limited only by the characteristics of the tractor to which it is attached. Control of the machine in the row is less satisfactory. The coulters and jointers which prepare the row for the topping operation interfere with steering. The rough condition in which the ground is left by the plow combined with the tendency of a wheel tractor to follow deep furrows makes control difficult under some conditions. The relatively heavy draft imposed by the plow and its standards tends to produce wheel slip and its accompanying side draft.

Fortunately the plow is relatively insensitive to off-row operation, so these factors do not prevent successful operation. Improvement in these respects is, however, imperative if the machine is to operate at maximum efficiency.

The complexity of the mechanism is one of the major defects in this system of harvesting. Whether or not the machine can be built with the required degree of fieldworthiness at a figure which would justify its use is a problem for commercial interests.

In general the present machine is functionally satisfactory in all operations excepting root recovery and will be worthy of consideration as a practical machine only if it can be greatly improved in this respect. The possibilities have not been exhausted, and a new model is now under construction.

Objectives for 1946

1. Increase average recovery to 92-95 percent.
2. Improve topper performance in wet, weedy fields.
3. Improve control of machine in the row.
4. Simplify digging and elevating units.
5. Harvest 40 to 50 acres of beets under a wide range of conditions.

Results of Survey of Sugar Beet Harvester Performance

G. W. Howard[1]

Ever since the beet industry started in the United States, people have given thought to mechanical harvesting of the crop. Many ideas now being put into good effect for harvesters were thought up 35 or 40 years ago. When improved in the manner in which they have been, they are quite effective in making successful harvesting machinery. Lots of progress has been made in the last few years in the development of such equipment. During the past few months, the Foundation has checked on some 25 or more harvesters. Many of these are in the experimental stage, but no inventor is passed up idly because he may have some promise of new ideas. I feel that we are in about the stage that the automobile was in 1915 and with machines in the hands of farmers rapid development will take place. Refinement in drives, separation of clods from beets, handling tops, and the other things that make a complete harvester are gradually resulting. Only about 10 percent of the acreage in sugar beets in the United States in 1945 was harvested mechanically but in some sections in California, where long harvest periods prevail, as much as 87 percent of the crop was entirely handled by machinery. On the basis of a survey made last fall of the industry, there should be around 25 percent of the crop harvested mechanically in 1946. This, of course, depends upon productive capacity of the manufacturers. At the present time this figure of 25% seems a little high. This same survey indicated that in the areas growing beets in the United States, 60 percent of the acreage was affected by clods and would require a machine which would properly handle this problem. About 7 percent of the acreage had the problem of rocks which would require a different machine. The survey also indicated that opinion as to the popularity of single-operation machines was about equally divided with a two unit harvester. In other words, about one-half of the areas favored a machine which would handle the crop in two parts, taking care of the tops with the first operation and lifting and handling the roots in the second. It is interesting to note also that farmers on about 86 percent of the acreage included in the survey favored harvesting machines that properly salvaged the beet tops. This would indicate that quite a stress is being made on the importance of the feeding value in the by-products that in many areas are more or less wasted at the present time.

Building a universal harvester probably will never be quite pos-

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[1]Staff Engineer, Beet Sugar Development Foundation, Fort Collins, Colo.

sible because of the variation in size of farming units, difference in climatic conditions, and other factors which influence mechanical operations, such as variation in width of rows, heighth of beets out of the ground, lack of foliage, deep irrigation ditches, bed planting and similar items. For instance, the beet contracts vary in size from 6½ acres in Wisconsin to 87 acres in Southern California. This means that in order to make mechanical work economical on the small units, custom work will probably prevail or two or three farmers will have to go together in owning the equipment. Such things are quite possible, as evidenced by present handling of grain combines and threshing machines. There is a variation in row widths from 18 inches in Minnesota to 42 inches in part of Northern California, with various widths between these two limits. I am merely pointing out these peculiar differences which would seem to make a common type harvester rather improbable.

I would like to deseribe briefly some of the machines that are in the productive and experimental stages:

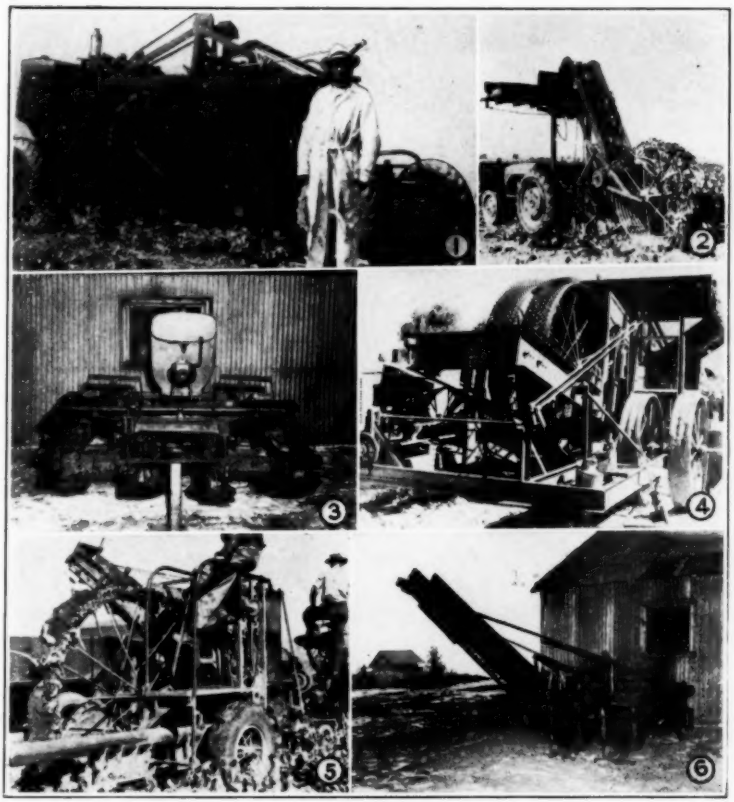
Marbeet

This machine is manufactured by the Blackwelder Manufacturing Company of Rio Vista, Calif. There are three sizes or types of the machine, which includes a two-row machine commonly pulled by a D-6, D-8, or T-12 size tractor. The machine has a large capacity and over 500 tons has been reported as harvested in a single day. The machine is a single-operation harvester. My means of spikes on the rim of 6-foot-diameter wheels it lifts the beets and carries them to the top of the machine where the roots are separated from the tops by means of chisels and a sickle bar to remove loose petioles. The roots are then taken over a scroll type screen and into an elevator to the truck. The machine requires from 24 to 32 end rows for efficient turning at the ends of the fields. It is sturdily built for handling dry, heavy soils.

A large one-row Marbeet machine of similar construction is quite popular, particularly in Southern California, for single-row beds.

A Marbeet Jr. one-row machine was designed in 1945 and is powered by a tractor of the size of Interantional "M". This machine is smooth, is powered with V-belt drives, and is capable of handling beets under rather difficult harvesting conditions.

Last year there were approvimately 150 of the Marbeet harvesters in operation, the majority of which were two-row machines. According to present information about 60 of the two-row machines and about 200 of the smaller one-row machines will be built.



1—Julius Sisbc two-row complete harvester; 2—Ford-Ferguson topper; 3—Kiest four-row topper; 4—Marbeet two-row harvester; 5—Marbeet Junior operating on Herbert Spencer farm at Fort Collins, Colo.; 6—Kiest two-row digger and loader.

John Deere

About 650 one-row harvesters have been built by the John Deere Wagon Works of Moline, Ill., during the last 3 years. This company is also experimenting with a two-row two-unit harvester. The one-row John Deere machine is designed for the Model "A" tractor and completely harvests the crop to the evtent of delivering six or eight rows of beets into a windrow with three to four rows of tops windrowed along both sides. The machine is very popular in many areas because the topping performance is very satisfactory and the handling of the tops is equally popular with the farmers who feed. A field

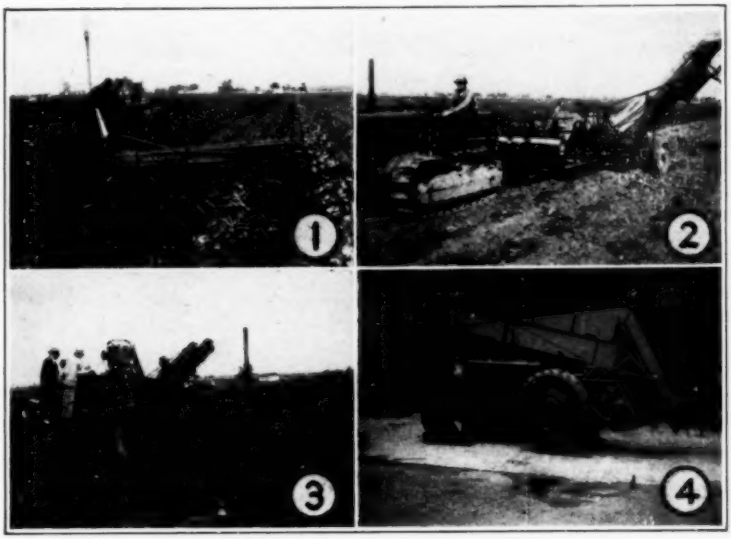
loader is required to elevate the beets from the windrows into trucks. Since the machine was originally built it has been considerably strengthened and improved in design. The topping is done with a "moon-shaped knife while the beets are still in the ground. The experimental model harvester is still in the development stage and very little can be explained concerning that at the present time. It is expected that at least 500 of the single-row John Deere harvesters will be made vailable for 1946 harvesting of the crop. The machine has some limitations as to soil, moisture, and soil types but on the whole has given very satisfactory results, particularly on acreages from 40 to 60 acres, harvesting daily an average of 5.2 tons per hour on the basis of reports from many areas. The machine has a capacity per hour of from 3½ to 6 tons, although one case has been reported of 15 tons per hour in a field yielding 25 tons per acre.

International

This machine is being built by International Harvester Company and is designed for one-row operation. It is unique in that a trailer is pulled behind a Model "H" tractor. The beets are topped in the ground by a disk-type knife with the tops moved the distance of the adjacent row where they can later be picked up and windrowed. The beets and soil are taken from a width of about 8 inches, and are lifted and carried over a Reinks type screen into the elevator. If there are clods, the beets are dumped directly onto a trailer and subsequently are loaded into a truck or wagon at the end of the field by use of a power takeoff operated elevator. The trailer holds between 2,500 and 3,000 pounds of beets and is mounted on two wheels which coincide in width to that of the four wheels of the tractor. If clods are a problem, a 36-inch sorting belt runs directly over the top of the trailer with two men pushing or pulling the beets off the belt into the trailer, the clods then roll over and onto the ground. This belt travels at half ground speed and permits 100 percent elimination of clods as well as a chance to trim beets that are insufficiently topped. In time studies last season the machine had a capacity of about 4½ tons per hour in California and about 3 to 5 tons in Colorado. It is expected that at least 300 to 500 of the Interantional harvesters may be available if production facilities can be stepped up.

Scott-Urschel

This is a one-row harvester, manufactured by the Scott-Viner Company of Columbus, Ohio. Fourteen of these machines were in operation in 1945 and it is hoped that perhaps 135 can be built for the 1946 esason. The machine has been experimented with for 12 or 15 years and gradual improvements have taken place in its design. In principle it seizes the foliage of the beet between rollers at the same



1—John Deere harvester operating at Scottsbluff, Nebr.; 2—E. L. Wilkins machine at Las Animas, Colo.; 3—International Harvester at LaSalle, Colo.; 4—University of California harvester.

time that an "L-shaped" type lifter breaks the tap root of the beet. The topping is done very accurately at the upper part of the machine by means of selective rods which are accentuated by a pair of unique heads. The new improvements offer greater screening of the roots and a better handling of the tops. The machine has an average capacity of about 5 acres per day.

Keist

This is a two-unit machine to be built by the Olson Manufacturing Company of Boise, Idaho. In the first operation four or six rows are topped at one time with the foliage carried into a vehicle by means of a conveyor at the rear of the bell type top rim mechanism. The second operation will lift and elevate into trucks two or three rows at one time. One of the improvements that has been planned is the use of Reinks type rolls to eliminate clods and dirt in two operations. The machine is studily built and should prove quite popular. There have been about 20 of the machines built; it is planned to dismantle and rebuild these. There may be from 100 to 200 of these machines available this year with improvements particularly in use of the V-belt drives. The capacity of the machine has not yet been determined but

probably should be from 8 to 12 acres per day with the possibility in light soil of even higher performances.

Flintjer

This machine is a one-row harvester designed by W. J. Flintjer of Cheyenne, Wyo. The beets are pulled by more or less conventional puller points with the tops being seized between sections of rubber cylinders. The topping is done with circular knives at the top of the machine, with the beets being conveyed directly into a truck or windrow. The machine is well designed and should prove quite popular, particularly for contracts of from 40 to 60 acres in size.

Silver

This machine probably will be based upon an experimental model engineered by the Great Western Sugar Company during the past 12 years. It will be manufactured by the Silver Engineering Works of Denver, Colo. A unique feature of the machine is the clod separating chains. The machine probably will be a two-row two-unit outfit. It is uncertain at the present time how many machines might be attempted this season.

Sishc

This machine has been experimented with for several years by Julius Sishc of Torrington, Wyo., who has had a great deal of experience in building the popular "Sishc" field loader. Changes and improvements are being made in the model which operated in 1945. No definite statement can be made as yet as to the details of this machine but it is hoped that it can be completed in time to make a contribution to the harvest of 1947.

Healy

This machine was designed by Alexander Healy, Jr., and is being built by the H-Engine Company of Billings, Mont. It is a one-row complete harvester which operates on a wringer roll principle with the beets being topped out of the ground. The machine is simple in design and can be cheaply built. It is planned to test the machine in the Imperial Valley in California this spring.

Harvall

This machine is being built by the Sterling Machine Company of Minneapolis, Minn. This is a two-row complete harvester which operated very successfully in the 1945 season in the Red River Valley in Minnesota. The principle of this machine is a series of 6-foot-diameter rims on the outside perimeter of which are 2-inch "Christmas tree shaped spikes. The lifter points are rather simple in

design and do not impale much dirt on the rims. The topping is done with two circular saws with the crowns of the beets being elevated to the proper height by a series of cog wheels. The machine should have a capacity of around 10 acres per day when powered by a caterpillar type tractor. It is planned to build 16 of these machines for the 1946 harvest.

Wilkins

This is a machine designed by E. L. Wilkins of Las Animas, Colo., and is a two-row complete harvester. The beets are topped by rather simple disk toppers while in the ground, with the beets being elevated in separate troughs onto a screen from where they are placed into the truck traveling alongside. The machine is still in the experimental stage but there may be others constructed for the 1946 season.

Braden

This machine was designed by John L. Braden of the Olson Manufacturing Company of Boise, Idaho. The topping is done in the ground by a knife which splits the crowns. The tops are put into windrows by a small attached side-delivery rake. One improvement that is planned for this year is a Reinks type screen to assist in dirt and clod elimination.

Hall

This machine was designed by J. L. and Harold Hall, of Wapato, Wash. It is a four-row two-unit machine having a lawn mower type topping machanism. At the present time no effort has been made to salvage chopped up tops. The machine is very simply designed and has some interesting ideas.

Nicholson

This machine is a four-row topper and four-row harvester which is being built by Oscar W. Nicholson, of Riverton, Wyo., for operation in 1946. Very little can be said about its performance as yet.

Nichols

This machine is a two-unit and either a one or two-row outfit. The topping is done in the ground by a lawn mower type device, with an effort being made to conserve the tops that are chopped up. It is contemplated to construct 10 or 20 of these machines for the 1946 harvest which will include some improvements in screening.

Ford-Ferguson

This machine is being developed by Harry Ferguson, Inc., and work has been taking place on it in the last 3 years in the vicinity

of Greeley, Colo. The machine will probably be a two-unit outfit with two rows topped and the tops elevated by a wheel mechanism into a vehicle alongside. Two rows of beets will be lifted by a unique type of lifter and elevated into a truck. Topping is done by means of a knife which is controlled by a clever linkage device. The top disposals and clod elimination appear to be excellent. It is hoped that a number of these machines might be built in time for the 1946 harvest.

Rassmann

This machine has been designed by Hugo Rassman of the Diamond Iron Works of Minenapolis. It is a one-row complete harvester but very little can yet be said about its performance.

University of California

This machine was designed by the engineering staff at the University and is a one-row complete harvester. One unique feature of the machine is that it carries about 1 ton of beets in a conveyor bin over one side of the tractor. The beets are grasped and carried up an open elevator which largely removes clods. The topping is done by a straight blade with a clinging finger pushing the tops against a baffle board out of the way of the wheels of the tractor. Improvements are being made of the gear and drives with a more gradual slope also being given to the puller points and elevator. The machine harvested about 24 acres in 1945 and it appears to be on the way to being an acceptable harvester machine, particularly for small contracts where there is not room for large machines.

Grew

This machine was designed by Dolphus Grew of Saginaw, Mich., and tops and handles one row at a time. The beets are lifted by a large diameter wheel which is equipped with spring type spokes that seize the beet out of the ground, elevating it to a hopper on the machine. This machine is very simple, light in weight, and has some excellent possibilities.

Hydrographic

This consists of six-row windrower, manufactured by the Hydrographic Company of Seattle, Wash. Beets have to be topped by hand.

There are a number of other experimental machines which are still in their initial stages. This would include Bowman Wheel harvester of Chaska, Minn., Wright cam type wheel harvester of Berthoud, Colo., Ellwein harvester of Sidney, Mont., and the James A. Harwood two-row harvester of Deaver, Wyo.

CHEMISTRY

Suggested Procedure For Obtaining Lower Temperatures During Sugar Beet Storage

C. A. Fort[1] and Myron Stout[2]

Better conservation of the sucrose beets during their storage rerains an extremely important problem. If the domestic beet sugar industry is to attain an overall economy of operation permitting successful competition with other sources of sugar, it is definitely necessary to eliminate a large part of the sugar loss usually occurring in piled beets. Further, this objective most be reached in spite of extending the storage period to permit longer operation of the factories. Only rough approximations can be made as to the present annual loss but certainly it amounts to tens of millions of pounds of sugar. It seems possible that as much as two-thirds of this loss is preventable.

It is well established that at temperatures between 32° and 40° F. the respiration of the beets and the destructive action of microorganisms are very slow and the resulting sugar losses correspondingly low. Both respiration and spoilage increases rapidly with increases in temperature. Therefore, the primary problem is to find practical means of obtaining low- temperature storage so that the quantity of trash, beet growth, beet quality, topping level, and other variables which seriously affect storageability at higher temperatures, become unimportant. This report deals with a preliminary experiment made in the 1945 campaign near Salt Lake City, Utah, which yielded promising results.[3] It was only a 75-ton experiment so it cannot be taken as conclusive, and the engineering problems involved in the adoption of the procedure to large-scale operations have only been casually considered. However, the principles underlying the experiment are believed to be basically sound and it seems proper to give this summary of the work in spite of its preliminary character. For the sake of brevity a review of pertinent literature will be omitted.

Discussion of Principles

The first fact of which use was made concerns the excellent storage temperatures which nature supplies during the nights of the harvest period. To assure a clear picture of this, Weather Bureau temperature records for a representative location in each of eight states

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[1]Bureau of Agricultural and Industrial Chemistry.

[2]Bureau of Plant Industry, Soils, and Agricultural Engineering, Agricultural Research Administration, Department of Agriculture. Agricultural Chemical Research Division Contribution No. 177.

[3]Acknowledgment is made for the cooperation of the management and personnel of the Utah-Idaho Sugar Company. The bin and the beets used were supplied by this company along with other services necessary to establishing the experiment.

Table 1.—Day and night temperatures during harvest months (average for 1943 and 1944).

Location	October				November			
	Mean maximum °F	Mean minimum °F	Typical hot day		Mean maximum °F	Mean minimum °F	Typical hot day	
			Maximum °F	Minimum °F			Maximum °F	Minimum °F
California, Stockton	80	44	96	47	68	36	79	34
Colorado, Fort Morgan	67	32	83	28	54	20	78	22
Idaho, Idaho Falls	61	34	77	34	44	25	59	26
Michigan, Lansing	59	41	77	48	45	30	63	42
Montana, Missoula	60	39	82	40	42	28	55	26
Nebraska, Scottsbluff	60	32	90	40	53	19	78	31
Utah, Salt Lake City	67	45	86	49	53	33	69	46
Wyoming, Torrington	67	30	83	27	55	20	75	24

for October and November 1943 and 1944 are presented in table 1. It will be seen that even though the October temperatures are the means for the entire month, rather than for only the latter part when storage piles are started, the mean night minima temperatures in most of these states is below 40° F. The smallest difference between day and night temperatures during these months are in Michigan, but the night temperatures are quite satisfactory. In November the night minima temperatures are mostly below 30° F. It is obvious that if the storage piles remained at these night temperatures the sugar losses would be low. However, the generally high daytime temperatures, the heat from respiration of the beets, and the heat from the decaying green trash tend to keep a beet pile well above night temperatures. While at night the heat rising from the piles pulls in the colder night air, in the daytime this accumulated colder air tends to drain out of the pile (due to its higher specific gravity) and the warm air drawn in is cooled by contact with the beets and in turn flows out. Of course, the temperature inside a large pile of beets changes very slowly; however, the general effect of this "breathing" of the pile, as it is often called, results in a temperature in the pile which is usually above daily mean temperatures. As will be seen, the experiment performed makes use of the colder night air to some extent and was designed also to reduce the loss of the accumulated cold air during the daytime. Finally, in line with the recent publication of this Department on the merits of whitewashing the outside of beet piles (*2*)[4] use is made of this procedure to reduce further the warming up of the exposed beets by the sunshine.

Experimental

To provide retention of cool temperatures in the beets, once they are obtained, the ideal is a four-walled storage bin with only the top

[4]Italic numbers in parentheses refer to literature cited.

open. In practice it was necessary to use a three-sided bin and make a temporary closure of the one end which could be removed for the purpose of reclaiming the beets. The experimental bin was constructed of 4-inch lumber, the dimensions being 10 feet high, 15 feet wide, and 20 feet long. The walls were well braced. The inside walls were lined with tar paper, using a cement to make the finished job as air tight as possible. To provide for the use of night air for cooling, two shallow air ducts were dug in the floor of the bin. Those ducts were about 6 inches deep and 12 inches wide and were spaced about six feet apart and equal distances from the ends of the bin. They extended under the one side wall and across the floor to within a couple feet of the opposite side. They were covered with steel flume covers spaced about 3 inches apart. Outside the bin the two ducts were brought together into a header box which had a vertical 7-inch pipe outlet for connection to a blower. These outside portions of the ducts were covered with lumber, tar paper, and dirt to make them air tight. A quarter-horsepower blower was attached. After a couple of days the motor was equipped with a time clock so that the operation of the blower could be set for the selected hours.

The bin was filled from a piling conveyor with trucked beets as received. The first beets were considerably bruised by the 10-foot drop, and the trash and dirt not removed by the cleaner appeared to be greater than normal. When the bin was slightly less than half full, ten 30-beet samples, protected in heavy wire baskets, were spaced in the bin at scattered positions. This was at about 5 feet above the ground. The filling of the bin was then continued until it was overflowing. At the open end the beets were repiled by hand to give a steep slope which was then covered with a large tarpaulin and tar paper. The sides and bottom of these coverings were attached to walls and ground to give as nearly air-tight protection as possible. The beets on top of the bin were somewhat leveled off and spray whitewashed with a mixed slurry of slaked lime and lime cake.

The samples placed in the experimental bin were selected as follows: A portion of an arriving truck load of beets was dumped and from this were selected three samples at a time, placing a beet of similar size and type in each sample simultaneously. One of these three samples was put in a waterproofed sack and used for the initial analyses. The second sample was used for placement in the bin and the third for placement in the regular factory storage pile adjacent to the bin. This process was repeated until there were ten samples for each purpose. All samples were weighed to within a quarter of a pound, the weight averaging about 75 pounds per sample. The 10 samples used for the original analyses were washed and reweighed to obtain an average dirt tare which was applied to all weights.

The experimental bin was filled on October 16, 1945, a few days before the regular factory pile was started. Six days later the set of samples for the factory pile were placed, five samples at each of two levels in the center of the pile, that is, about 25 feet in from the sides at 5- and 10-foot levels, respectively. In both the bin and pile the bulbs of recording thermometers were placed adjacent to the special beet samples, three in the bin and two in the factory pile. The cables were protected by pipes, but the bulbs of the thermometers extended into the beets. The exposed outide ends of the pipes were sealed to prevent flow of air.

The day the bin was filled was relatively warm, the initial temperature of the beets being 60° F. The blower was not yet installed and by the next noon the temperature had risen to 63° F. That second night, forced ventilation was used from 5 p. m. until 9 a. m. the next morning, and the temperature in the bin was lowered by 10 degrees. For the next 5 nights the blower was operated by the time clock from midnight until 6 a. m. The temperature was then down to 40° F. and the use of the blower was discontinued. The temperatures remained below this point for the following week in spite of daytime temperatures in the 70's. Relatively high night temperatures then gradually raised the temperature to 45° and the blower was again used for 3 hours per night for 5 nights. However, as the first nights of this period were above the bin temperature the effect was to continue the temperature rise. Then as night minima were again low the temperature in the bin was quickly brought down below 40° F. and remained below 35° F. for most of the following storage period without further use of the forced ventilation with night air, although daytime temperatures were frequently in the 60's. The whitewashing was renewed once, after about 2 weeks of storage.

The experience in this second period of using the blower demonstrated the desirability of a thermometric control on the blower so that it would be in service only when the outside temperature was below the storage temperature. Such an arrangement should also preclude operation of the blower when outside temperatures were more than a few degrees below freezing.

At the time of placing the samples in the factory pile it was rainy, cool weather and initial temperatures were not as high but they remained above 50° F. for around 2 weeks and at all times remained 10 or more degrees F. above the temperatures in the bin. The mean temperature for the entire storage period in the bin and in the pile were 35° F. and 45° F. respectively.

Experimental Results

Unfortunately, from the viewpoint of the direct comparison of the pile storage and bin storage, it was necessary to reclaim eight of the samples from the factory pile after a period of 51 days. The 10 bin samples and 2 remaining samples from the pile were reclaimed after 77 days. Even at the 51-day period the beets of the factory pile showed scattered spoilage, although the samples in the pile were not affected. At the 77-day storage period the spoilage in the pile had increased markedly but the samples recovered again were little affected. On the other hand, the beets in the bin were all in excellent physical condition, free from spoilage and as firm as fresh beets. Even where the trash was excessive under the piling cone the condition of the beets was perfect. The special samples for test were likewise sound and when split were clear and white even to the tip of the roots.

The comparative results of storing beets in the factory pile and in the experimental bin are presented in table 2. The values given are the means of the number of samples indicated and in the case of the reclaimed beets are calculated to the original weight basis. For the samples from the factory pile which had sustained considerable weight loss, an adjusted normal weight was used roughly equivalent to a normal weight on the fresh weight basis so that the effect of the mare would be the same as when testing fresh beets. True sucrose and raffinose were estimated by the double enzyme method and the corresponding formula. In addition the true sucrose and raffinose were estimated on the basis of the determination of the total reducing sugars after invertase inversion and after the invertase-melibiase inversion. The differences in these values were calculated to raffinose and the remainders, after correction for direct reducing sugars and the raffinose were calculated to sucrose. In table 2 the results by this procedure are designated as "chemical" data, as opposed to the results obtained by polariscopic methods.

Discussion

It is evident from the data as given in table 2 that greater losses of sugar were sustained by the beets in the factory pile in 51 days than in the experimental bin in 77 days. In order to compare the results more correctly it is necessary to calculate to a daily rate basis. This has been done, and the values obtained for the pounds of sugar lost per ton of beets per day are summarized in table 3.

It may be noted that the figures for true sucrose and solids are a mean of 5 methods of estimation on the 10 samples at each condition. For the sucrose these methods were true sucrose by polarization and

Table 2.—Comparative results on beets stored in factory pile and in experimental bin.

	Initial analyses	Reclaimed beets (on fresh weight basis)					
		Factory pile				Experimental bin	
Duration of storage, days	....	51		77		77	
Number of samples	10	8		2		10	
Weight shrinkage, percentage on beets	....	8.7		8.9		2.4	
		Analyses	Change	Analyses	Change	Analyses	Change
Apparent sucrose (direct polarization), percentage on beets	16.97	16.22	−0.75	16.01	−0.96	16.66	−0.31
True sucrose (polarscopic), percentage on beets	16.67	16.05	0.62	....	....	16.36	−0.31
True sucrose (chemical), percentage on beets	16.58	15.90	−0.68	....	....	16.12	−0.46
Reducing sugars, percentage on beets	0.09	0.18	+0.09	0.33	+0.24	0.14	+0.05
Raffinose (polariscopic), percentage on beets	0.18	0.11	−0.07	....	....	0.10	−0.08
Raffinose (chemical), percentage on beets	0.27	0.33	+0.06	....	....	0.28	+0.01
Total sugars (polariscopic), percentage on beets	16.94	16.34	−0.60	....	....	16.60	−0.34
Total sugars (chemical), percentage on beets	16.94	16.41	−0.53	....	....	16.54	−0.40
Total dry solids, percentage on beets	23.98	23.23	−0.75	23.28	−0.70	23.40	−0.58
Diffusable dry solids, percentage on beets	19.49	18.89	−0.60	18.89	−0.60	19.07	−0.42
Total sugars: reducing sugars (chemical), percentage on beets	17.78	17.22	−0.56	....	....	17.36	−0.42
Marc (non-diffusable solids), percentage on beets	4.49	4.34	−0.15	4.39	−0.10	4.33	−0.16
Total nitrogen in juice, percentage on beets	0.166	0.165	....	0.167	....	0.168	....
Non-protein nitrogen in juice, percentage on beets	0.106	0.119	+0.013	+0.116	+0.010	0.118	+0.012
Ratio non-protein to total nitrogen	63.8	72.1	+8.3	69.5	+5.7	70.2	+6.4
Apparent purity	87.1	85.9	−1.2	84.8	−2.3	87.4	+0.3
True purity (polariscopic)	85.5	85.0	−0.5	....	....	85.8	+0.3
True purity (chemical)	85.1	84.2	−0.9	....	....	84.6	−0.5

Table 3.—Summary of storage losses (expressed in pounds per ton of beets per day of storage).

	Factory pile	Experimental bin
Apparent sucrose	0.28	0.08
True sucrose, (mean of 5 methods)	0.26	0.12
True solids, (mean of 5 methods)	0.22	0.11
Inversion loss	0.04	0.01
Respiration loss*	0.22	0.11
Respiration loss**	0.19	0.11

*Estimated from respiration data of Pack for 45° and 35° F. respectively.
**Estimated from respiration data of Barr, Mervine, and Bice.

by the chemical method, total and diffusable solids plus the sucrose equivalent of the increase in reducing sugars, and the total sugars determined as reducing sugars plus the sucrose equivalent of the increase in reducing sugars. In a similar manner in addition to the loss of solids determined by total dry solids, diffusable dry solids, and total sugars as reducing sugars, there were included the values for the true sucrose changes minus the increase in direct reducing sugars. All 10 samples from the factory pile were included in these general averages. By statistical analysis the differences between pile and bin storage are highly significant when put on the basis of the same period of storage.

There is a difference between sucrose loss and actual sugar solids lost. The former includes inversion as indicated by increases in reducing sugar content as well as the sucrose destroyed by respiration (or action of microorganisms). The loss of true solids is primarily just the sugar consumed during the storage. From the viewpoint of practical recovery of sugar the total loss is the more important value, that is, inversion of sucrose is as surely a source of loss as complete destruction of the sucrose. However, from the viewpoint of plant physiology it is of interest to note that the actual consumption of sugars (loss of solids) corresponds to the respiration rates determined by Pack (*3*) and by Barr, Mervine, and Bice (*1*) for the temperatures of 45° F. and 35° F. respectively.

If in addition to the direct losses indicated by the values presented one also considers the effect of the changes in purity on the recovery of the sucrose, the resulting comparison shows a decrease of 0.28 pounds to recoverable sugar per ton per day in the case of the beets in the pile as contrasted with a figure of 0.10 pound for the beets in the bin. Irrespective of the means used for obtaining this 10-degree F. reduction in storage temperature it is certain that such a differential in temperature will produce this saving in sugar. Taking as an example a 50,000-ton pile of beets stored for 50 days, this means a conservation of 450,000 pounds of sugar. Taking the domes-

tic industry as a whole a general reduction of storage temperatures by 10 degrees would save in the vicinity of 20 millions pounds of sugar. These estimates are conservative because they do not include any loss due to spoilage; also at any temperature level above the range found in this experiment the saving resulting from a 10-degree lower temperature would be greater.

No claim is made on the basis of the preliminary small-scale experiment such as this that the particular techniques used are practical or will for certain produce a 10-degree reduction in the storage temperature of a large pile. However, from this experiment and comprehensive basic studies which have been carried on at Salt Lake City the past 4 years and from the evidence reported in the literature, it seems certain that the following conditions must be met: (1) The direct sunlight should be reflected by a white coating on the surface beets; (2) the beets should be cooled below 40° F. as promptly as possible after piling and the low night temperatures prevalent during the harvest can be utilized to do this; (3) the sides of the pile should be protected by air-tight walls to prevent loss of the cooling produced at night and to generally restrict circulation of air.

It is believed that the use of forced ventilation should be restricted to that actually needed to get the desired low temperature. Once at the low temperature the heat of respiration will be low, and with the daytime heat shut out or reflected the beets will remain cool and in humid atmosphere which will keep both weight and sugar losses at a practical minimum. In locations where night minima are above 40° F. the acception of a slightly higher storage temperature is possibly unavoidable, but it is possible that compared with the normal pile storage the advantage of cooling will remain.

Summary

The experiment under discussion compared beets stored in a special bin with corresponding beets stored in the adjacent factory pile. The special bin was essentially air tight on all four sides and was provided with air ducts in the floor through which cool night air was forced several hours each night for the first 6 nights to reduce the beet temperature to near the freezing point. The forced ventilation was then discontinued and, since the sides of the bin prevented loss of cold air through drainage, the bin temperature remained satisfactorily low for the 77-day duration of the test. Additional protection against heating by the daytime sunshine was provided by whitewashing the open top surface of the bin.

A differential of 10° F. between the two storage conditions and the reduced circulation produced by the bin kept weight shrinkage

at a low level. In spite of considerable bruising in filling the bin and in spite of what appeared to be an abnormal amount of trash and dirt, the beets in the bin were reclaimed in excellent physical condition. The special samples of known initial composition lost only 0.12 pound of sucrose per ton of beets per day of storage as compared with 0.26 pound per ton per day in the factory pile.

The application of these principles, of reduced circulation of air through the beets and the use of the cold night air for cooling the beets immediately after piling, to large-scale storage may, at a moderate cost, conserve a very considerable part of the sugar normally lost.

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A Short Method For Calculating Outage For Loading of Molasses Tank Cars

H. M. BAUSERMAN[1]

It is required by railroad companies that molasses cars set for loading shall be loaded within certain limits of weight. It is desirable, and generally permissible, to load over the "capacity" weight stenciled on the car but not to exceed a certain maximum weight. This maximum is usually 110 percent of the "capacity" weight, or the maximum may in some instances be stenciled on the car as "Ld. Limit" (load limit). Where track scales are not provided at the loading station, it is necessary to calculate the required outage in order that the weight of the load will more than equal the indicated railroad capacity weight but be less than the maximum of 110 percent of the capacity weight, or that it shall not exceed the stipulated load limit.

The computation of outage for the filling of a car to the proper load weight involves essentially a calculation of the volume of the liquid of given density, in this case molasses, such that the calculated volume of liquid will have a weight equal to the desired loading. Calculations with this object can be greatly simplified by the use of tables of constants. It is the purpose of this paper to show how such tables can be constructed and applied.

Development of Procedure

Assuming that the volume capacity of a car is greater than the permissible loading, the relationship between the loading permitted or desired and the total weight capacity of the car, which relationship we may designate by the factor f, would be expressed by the equation

$$(1)\quad f = \frac{\text{Load weight desired (pounds)}}{\text{Load weight of completely filled car (pounds)}}$$

Since a certain overload of defined limitations in excess of the indicated weight capacity is permitted, and usually desired, equation (1) may be written

$$(2)\quad f = \frac{\text{Indicated load weight capacity (pounds)} \times \text{Percent capacity loading}}{\text{Volume capacity in gallons} \times \text{weight per gallon}}$$

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[1]Chief Chemist, Grand Island Factory, American Crystal Sugar Company.

This paper was presented by F. W. Weitz, General Chemist, American Crystal Sugar Co. The author wishes to express his appreciation for the many valuable suggestions made by Mr. F. W. Weitz while this paper was being prepared.

or

$$(3)\quad f = \frac{\text{Indicated load weight capacity (pounds)}}{\text{Volume capacity in gallons}} \times \frac{\text{Percent capacity loading}}{\text{Weight per gallon}}$$

Now, letting K represent the second factor in equation (3)

$$(4)\quad K = \frac{\text{Percent capacity loading}}{\text{Weight per gallon}}, \text{ then}$$

$$(5)\quad f = \frac{\text{Indicated load weight capacity (pounds)}}{\text{Volume capacity in gallons}} \times K$$

Values for the factor K can be set up in a table for molasses of various densities and for a range of percentage of loadings over the capacity loadings. In table 1 values for the factor K are given for molasses densities ranging from 77.5 to 87.5 Brix by stages of 0.5 Brix and for fill of 100 to 110 percent of indicated capacity loadings.

Table 1.—Factor K.

Brix	Percent indicated capacity load						Pounds per gallon
	100	102	104	106	108	110	
77.5	.08594	.08766	.08938	.09110	.09282	.09453	11.635
78.0	.08574	.08746	.08917	.09089	.09260	.09432	11.662
78.5	.08554	.08725	.08896	.09068	.09239	.09410	11.690
79.0	.08534	.08705	.08876	.09047	.09217	.09388	11.717
79.5	.08514	.08684	.08855	.09025	.09195	.09336	11.745
80.0	.08494	.08664	.08834	.09004	.09174	.09343	11.773
80.5	.08474	.08643	.08813	.08982	.09152	.09321	11.800
81.0	.08454	.08623	.08793	.08962	.09131	.09300	11.828
81.5	.08435	.08603	.08772	.08941	.09109	.09278	11.856
82.0	.08415	.08583	.08751	.08920	.09088	.09256	11.884
82.5	.08395	.08563	.08731	.08899	.09066	.09234	11.912
83.0	.08375	.08543	.08710	.08878	.09045	.09213	11.940
83.5	.08355	.08522	.08689	.08856	.09023	.09190	11.968
84.0	.08335	.08502	.08669	.08836	.09002	.09169	11.997
84.5	.08316	.08482	.08649	.08815	.08981	.09148	12.025
85.0	.08296	.08462	.08628	.08794	.08960	.09126	12.054
85.5	.08277	.08442	.08608	.08773	.08939	.09104	12.082
86.0	.08257	.08422	.08587	.08752	.08918	.09083	12.111
86.5	.08237	.08402	.08567	.08731	.08896	.09061	12.139
87.0	.08218	.08383	.08547	.08711	.08876	.09040	12.168
87.5	.08199	.08363	.08527	.08691	.08855	.09019	12.197

Values for pounds per gallon used in deriving above K factors represent the weights in air calculated from apparent specific gravity 20/20 equivalent to the degree Brix, Table 114, Circular C 440, National Bureau of Standards.

Weight of 1 gallon of water at 20° C. in air against brass weights=8.3216 pounds.

Referring again to equation (1)

$$f = \frac{\text{Load weight desired (pounds)}}{\text{Load weight of completely filled ear (pounds)}}$$

If we let

l=length of the tank
d=diameter of the tank
h=height of fill in the tank
V=total volume of tank
V_1=volume of tank to height of fill

then

$$(6) \quad f = \frac{V_1 \times \text{Weight per unit volume}}{V \times \text{Weight per unit volume}}$$

The volume of the tank to the height of fill is computed by the formula

$$(7) \quad V_1 = l \left\{ \frac{3.1416\ d^2}{8} + \frac{2h-d}{2} \sqrt{hd-h^2} + \frac{d^2}{4} \text{ are sin } \frac{2h-d}{d} \right\}$$

and

$$(8) \quad V = l \left\{ \frac{3.1416\ d^2}{4} \right\}$$

Substituting these values for V_1 and V respectively in equation (6) we have

$$(9) \quad f = \frac{\dfrac{3.1416\ d^2}{8} + \dfrac{2h-d}{2} \sqrt{hd-h^2} + \dfrac{d^2}{4} \text{ are sin } \dfrac{2h-d}{d}}{\dfrac{3.1416\ d^2}{4}}$$

Values for f as the above with relation to the ratio h/d from .01 to 1.00 are available in a table published originally in Central blatt der Zucker Industrie, Feb. 10, 1911, page 108-109, and reprinted in General Methods and Data, 1925, page 124, American Crystal

Sugar Company. Several of the values as given in the table were selected at random and compared for agreement with values calculated by means of the above formula. Since the values agreed at the several random points checked in the table, free use was made of that table in arranging another table of factors.

The table referred to, as noted above, gives the factors f in relation to the ratio of the height of fill, i. e., the depth of the liquid, to the diameter of the tank. In loading tank cars, rather than to measure the height of fill it is more convenient to have the desired fill defined as outage, or the distance from the top of the tank to the top of the liquid. The table of factors of f for the ratios h/d was therefore rearranged for greater convenience to give values for u/d, where u stands for outage. The term outage as herein used is defined as the distance from the top of the tank to the top of the liquid, measured from the inside edge at the top of the main body of the tank and below the dome. Since u equals d-h then the factor f corresponding to u/d for given values of d and h is the same as the factor for 1-(h/d). Values for u/d equivalent to factor f are given in table 2.

Application of the Table for Computing Outage

With a few pertinent items of information relative to the loading and by the application of the tables, the determination of the appropriate outage for loading to the desired load weight can be reduced to one reference to each of the tables and a few simple calculations.

The required items of information pertaining to the loading will be the following:

(a) Brix of the molasses

(b) Desired percentage of indicated load weight capacity

(c) Indicated load weight capacity in pounds

(d) Volume capacity of the car in gallons (body only, see note below)

(e) Inside diameter of tank in inches

Item (a) will be provided from the analysis.

Item (b), the maximum, will usually be established by railroad rulings.

Items (c) and (d) will usually be found stenciled on the car body, either on the side or end of the tank. In this connection it is to be noted that, if no designation is made otherwise, the gallons capacity stenciled on the car usually includes the dome. The capacity of the dome can be computed; however no appreciable error will be introduced if it is estimated and a deduction made accordingly from

Table 2.—Factor $\frac{u}{d}$

f	$\frac{u}{d}$	f	$\frac{u}{d}$	f	$\frac{u}{d}$	f	$\frac{u}{d}$
1.0000	.00	.8045	.25	.5000	.50	.1955	.75
.9983	.01	.7934	.26	.4873	.51	.1845	.76
.9952	.02	.7822	.27	.4745	.52	.1738	.77
.9913	.03	.7708	.28	.4618	.53	.1631	.78
.9866	.04	.7593	.29	.4491	.54	.1527	.79
.9813	.05	.7477	.30	.4364	.55	.1424	.80
.9755	.06	.7360	.31	.4238	.56	.1323	.81
.9692	.07	.7241	.32	.4112	.57	.1224	.82
.9625	.08	.7122	.33	.3986	.58	.1127	.83
.9554	.09	.7002	.34	.3860	.59	.1033	.84
.9480	.10	.6881	.35	.3735	.60	.0941	.85
.9402	.11	.6759	.36	.3611	.61	.0851	.86
.9320	.12	.6636	.37	.3487	.62	.0764	.87
.9236	.13	.6513	.38	.3364	.63	.0680	.88
.9149	.14	.6389	.39	.3241	.64	.0598	.89
.9059	.15	.6265	.40	.3119	.65	.0520	.90
.8967	.16	.6140	.41	.2998	.66	.0446	.91
.8873	.17	.6014	.42	.2878	.67	.0375	.92
.8776	.18	.5888	.43	.2759	.68	.0308	.93
.8677	.19	.5762	.44	.2640	.69	.0245	.94
.8576	.20	.5636	.45	.2523	.70	.0187	.95
.8473	.21	.5509	.46	.2407	.71	.0134	.96
.8369	.22	.5382	.47	.2292	.72	.0087	.97
.8262	.23	.5255	.48	.2178	.73	.0048	.98
.8155	.24	.5127	.49	.2066	.74	.0017	.99
						.0000	1.00

u = Outage (main body of tank, not including dome)
d = Diameter of tank

$$f = \frac{\text{Indicated load weight capacity (pounds)}}{\text{Volume capacity (gallons)}} \times K \text{ (from table 1)}$$

the total stenciled capacity to obtain the gallons capacity of the body only.

Item (e), the diameter of the tank, is the only item of measurement on the car required for the calculation of the loading outage.

In table 1, in line with a Brix value in the first column, under the caption Brix, closest to that of the determined Brix of the molasses, and in the selected column under the heading of the desired percentage indicated capacity load, the appropriate factor K is found.

From equation (5)

$$f = \frac{\text{Indicated load weight capacity (pounds)}}{\text{Volume capacity in gallons}} \times K$$

By inserting in this equation items (c) and (d), established from the information stenciled on the car as mentioned above, and the numerical value for factor K derived from the table, the factor f is calculated.

Referring to table 2 the appropriate factor u/d will be found, corresponding to the factor f. Since u/d is the ratio factor of outage of the loaded tank to the total diameter, then

$$\text{Outage in inches} = \frac{u}{d} \times \text{diameter of the tank in inches.}$$

Note: The factors in table 2 are set up for a tank with straight parallel ends. Most cars have ends bumped outward, however, these ends should not be considered in the calculations. When a car is, as in the usual case, loaded nearly full,any small error introduced from this source will be more than compensated by the coil of pipe commonly found in the bottom of the car and used for heating the load. One of the greatest errors made in loading cars to predetermined weight is usually that of not loading the car to the calculated outage. This error, along with other unavoidable errors introduced in Brix determinations, temperature, foam measurement, and so forth will affect the final load weight to the extent that it will usually vary from the selected value by less than 1 percent.

An example will illustrate the procedure of calculation. The values were taken from our notebook and cover a car actually loaded.

(a)	Brix of the molasses	82.0
(b)	Desired percent of indicated load weight (108 percent was used rather than 110 percent to allow for any small errors.)	108.
(c)	Indicated load weight capacity in pounds	80,000.
(d)	Volume capacity of the car in gallons (8,044 stenciled on car, estimate dome 44, body only)	8,000.
(d)	Diameter of car in inches	79.

From table 1 it is found that

$K = 0.09088$

From equation (5) above

$$f = K \times \frac{\text{Indicated load weight capacity (pounds)}}{\text{Volume capacity (gallons)}}$$

$$f = 0.09088 \times \frac{80{,}000}{8{,}000} = 0.9088$$

Now finding u/d from table 2 that most nearly corresponds to 0.9088

$$u/d = .15$$

Then

$$\text{Outage} = u/d \times \text{diameter in inches}$$

$$\text{Outage} = .15 \times 79 = 11.85 \text{ inches}$$

The actual railroad weight of this load was 86,880 pounds. We attempted to load this car to 108 percent of 80,000 pounds or 86,400 pounds.

The percentage error then was

$$\frac{86{,}880}{86{,}400} \times 100 - 100 = 0.56 \text{ percent}$$

Application of the Tables in Estimating Load Weight of Cars

It is of frequent occurence that cars of molasses for processing are received in advance of receipt of their bills of lading, and it becomes necessary for immediate accounting purposes to apply temporarily, in lieu of the actual railroad weights, an estimated weight of the molasses received. By reversing the above procedure of calculation for estimation of required outage for loading of tank cars, the formulae and tables may likewise be used for approximating the load weight of a loaded car.

From the measured outage and the diameter of the tank the ratio of outage to diameter, u/d, may be determined and in table 2 a factor f equivalent to the ratio u/d will be found.

By substituting in equation (1) "load weight contained" for "load weight desired", we have

$$f = \frac{\text{load weight contained (pounds)}}{\text{Load weight of completely filled car (pounds)}}$$

which may be expressed as

$$f = \frac{\text{load weight contained (pounds)}}{\text{Volume capacity in gallons} \times \text{pounds per gallon}}$$

Then

load weight contained = volume capacity in gallons × pounds per gallon × f

An example will illustrate

Let d, diameter, inches	= 81	
u, outage, inches	= 11	
Volume capacity in gallons	=8,023	(body only)
Brix of molasses	= 81.5	

Then $\frac{u}{d} = \frac{11}{81} = .136$

From table 2 where $\frac{u}{d} = .136$, by interpolation it is found that

f = .918

From table 1 at 81.5 Brix

weight per gallon = 11.86 pounds

Then

Load weight contained =8,023 x 11.86 x .918=87,350 pounds.

Laboratory Equipment for Low Raw Operations

ROBERT J. BROWN[1]

It is often desirable to determine the effects of process changes on raw side operations, and the effects of such changes are generally difficult to determine in the factory itself. The principal questions to be answered are: What effect does the process change have on the purity of molasses and what is the effect on quality of raw sugar? Experience has shown that even factory trial does not always give the final answer because other variable factors may overbalance the effect of the one under trial. Hungerford, in January 1942, presented before this group data showing seasonal changes in crystallization rates of sugar from beet syrups, the changes being sufficient to mask completely the effects of process treatments being made in the factory during the periods represented by the samples he studied. Therefore it is desirable to have a laboratory procedure capable of giving a fair idea of what the effects of the syrup treatment would be in actual factory operations. The great advantage of the laboratory trial lies in the ability to compare liquors prepared by standard practice and by the new practice, from the identical beets, and thus eliminate the primary faults of factory trials.

The equipment consists of a pan, a crystallizer, and a laboratory centrifuge. The pan, with a capacity of 3,750 grams of dry matter, has a conical steam-jacketed basal section, and an inner sheet metal shell around which circulation develops. The pan is provided with thermometers for measuring massecuite temperature, a device for accurate control of pressure within the pan, a surface condenser, and a large burette for measuring the volume of the condensate. Pan liquor enters at the bottom and is weighed in from a balance.

The crystallizer is a modified 2-quart ice cream freezer. It is driven by a motor and reducing gears at 0.8 r.p.m. The mixing device of the freezer has been modified in two respects. The wooden scarper blades have been shaved off sufficiently to clear completely the can wall during rotation, so that grinding of sugar crystals is prevented. And the stirrer mechanism has been so shortened that it may be completely submerged by the massecuite, thus preventing incorporation of air during the cooling process. The top point of the shoulders which carry the wooden scrapers is 4¼ inches above the bottom of the can, and the can is filled with massecuite to a point

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about ½-inch above these shoulders. The stirrer mechanism rests on a washer.

Temperature control of cooling is maintained by circulation of water, held in a 50-gallon wooden barrel, around the can containing the massecuite. The water supply, heated to 70° C. at the time the massecuite is placed in the crystallizer, is permitted to cool spontaneously overnight, during which period the temperature drops to slightly below 40° C.

The centrifuge is a standard laboratory type machine, carrying an 8-inch basket.

A little practice with the equipment above described enables one to obtain very satisfactory results in duplicate tests. However, an accurate interpretation of the results requires an accurate knowledge of the properties of the liquors boiled.

The most important factor in the handling of the raws is the preparation of the pan liquor. The purities of the pan liquors must be accurately established, and since variations in juice or syrup treatments may cause changes in the polarization of non-sugars present, only enzyme hydrolysis may be depended upon in the sucrose analysis. Careful drying on sand is required for the dry substance determination. Once careful analysis of a liquor has been made, the relations between true and apparent sucrose and dry substance may be employed to establish factors, and subsequent analyses may consist of apparent purities and refrectometer dry substances.

The solubility of sugar in the liquors handled should be known, since it is generally necessary that comparative tests on different syrups be made by boiling at the same supersaturation.

Various investigators have published data on solubilities of sugar in impure solutions. Solubilities at constant purity and temperature vary decidedly in the raw pan purity range. If one is studying the effect of juice treatments which do not cause any appreciable effect on the composition of the impurities, he knows that the solubilities of sugars in the liquors is constant at constant purity and an accurate knowledge of solubility is unnecessary. It is only necessary that liquors be boiled under constant conditions of supersaturation at equivalent stages in the boiling process, and that the supersaturation be not sufficiently high to cause formation of false grain. But if treatments of liquors cause appreciable change in the composition of impurities, then solubility determinations on the differently prepared liquors are required. The shape of the solubility curves has been sufficiently well established that a single determination of solubility of sugar in the syrup in question somewhere within the range of 70 to 75 purity at about 70° C. suffices to yield the information necessary to permit one to calculate the concentrations required to

produce the desired degree of supersaturation while boiling in the pan.

However, many raw pan studies do not demand absolutely accurate knowledge of solubilities and in the work in this laboratory the data published in Ind. and Eng. Chem., Vol. 20, p. 1230 (Nov. 1928) and Vol. 25, p. 555 (May 1933) are generally used as the basis for calculations of concentrations at the various supersaturations.

In addition to a knowledge of solubilities, a knowledge of boiling points of solutions at varing purities and pressures is required. Such data have been published in the literature, but in this laboratory we employ unpublished data we have obtained.

With a knowledge of solubilities and boiling points, one is prepared to calculate a schedule of boiling. For low raw pans we have found a supersaturation of 1.04 to be very satisfactory.

$$\text{(Supersaturation} = \frac{\text{(Percentage dry substance in saturated pan liquor)}}{\text{(Percentage dry substance in pan liquor)}}\text{)}$$

We have also standardized on boiling at 70° C.

Calculations are made in advance to enable the operator to control the rate of drop in purity of the mother liquor, and as the purity drops the pan pressure is decreased to maintain the supersaturation at constant boiling temperature.

The boiling schedule shows the conditions which should exist at any instant during the boiling period. These conditions are: Quantity of pan liquor introduced; quantity of condensate removed; purity of mother liquor; pressure of boiling; and temperature, which remains constant.

It has been pointed out that a sugar solution of given purity and supersaturation can boil at the same temperature and pressure as another of higher purity and higher supersaturation, and therefore the boiling schedule may not reflect accurately the conditions within the pan. However, tests on mother liquor from the massecuite at the time the pan is dropped show a remarkably close agreement between actual and calculated purities, and furthermore, if conditions within the pan are continuously maintained on schedule, no opportunity is given for purities and supersaturations to depart from calculated values.

For preparation of boiling schedules we have standardized on 76.0 purity pan liquor at 70.0 dry substance, boiled at 70° C. Experience has shown that pan liquors should be carefully filtered before use or insoluble matter may completely upset results in the centrifuge. A graining charge of 1,200 grams of dry substance is brought to the supersaturation at which the pan is to be boiled and 20 grams of starch-free powdered sugar, suspended in saturated sugar solution,

are introduced through the feed line. The pan is then boiled according to the calculated schedule. At the end it will generally be found necessary to remove carefully some water, after all feed has been charged, since a mass dropped at the supersaturation at which boiling has been done will usually be of too low concentration to produce molasses of low purity. The equipment described will produce 60 purity molasses from a massecuite of about 91.5 percent dry substance.

After the massecuite is dropped from the pan, the crystallizer can is filled to the proper point and crystallization is permitted to proceed for 22 hours. Shortly before spinning, the massecuite temperature is raised to 40° C.

The centrifuge, basket and casing as well, are heated to a little above 40° C. One kilogram of massecuite is placed in the basket, which carries a standard sugar screen, and the massecuite is spun for a standard time at standard speed, say 3,000 r.p.m., for 10 minutes. The unwashed raw sugar is taken for analysis. Since the standard sugar screen is generally loosely fitting and permits the passage of an undue quantity of sugar into the mother liquor, the molasses sample is obtained by spinning a second batch on a finer, more closely fitting screen. The product so obtained is not crystal free but closely simulates molasses produced in factory operations.

The results in table 1 are given as an example of results obtainable with the above described equipment and procedure. The performances of five different liquors were compared.

Table 1.—Experimental boiling of raw massecuite. Pan liquor—purities 76.0, boiled at 1.04 supersaturation, in crystallizer 22 hours.

Liquor No.	Raw pan Dry substance	Molasses True purity	Raw sugar Apparent purity
1	—	58.7	89.9
1	91.8	59.0	92.6
2	—	59.1	90.2
2	91.6	59.1	92.5
3	91.3	60.2	93.1
3	91.8	60.1	92.8
4	92.1	60.1	87.8
4	91.2	61.1	91.9
5	91.4	60.9	91.9
5	91.8	61.1	92.3

Only on Liquor No. 4 did molasses purities fail to check, and this was evidently the result of too great variations in raw massecuite concentrations. Two of the massecuite dry substance samples were lost, and in both instances it appeared that the massecuites were slightly too heavy. Small variations in massecuite concentration obviously affect raw sugar purities much more than they do molasses purities.

Projectoscope

PAUL M. SMITH[1]

The desirability of a device by means of which an enlarged picture, so to speak, of massecuite, syrup, and sugar samples could be projected on a screen for visual inspection by several people simultaneously has been known for some time. While projectors have been designed for this purpose before, the one of which a description follows has some advantages over previous types, particularly in that the ground-glass viewing screen produces a better image and the instrument may be located in the factory on the pan floor, since it is not necessary that it be situated in a darkened room to be used.

The projector employs a standard Bausch and Lomb dissection microscope equipped with a 10x triplet lens. The other optical parts are two, being (1) a front surfaced, aluminized mirror 4 inches square and 3/16-inch thick inclined at an angle of 45° with respect to the optical axes of the microscope and the viewing screen and (2) a piece of ordinary double-strength window glass 7 inches square and ground on one side with No. 600 carborundum powder until the surface of the glass is completely frosted. It is not necessary that either the mirror or the viewing screen be optically flat. It is highly desirable, if not necessary, however, that the mirror be front-surfaced and aluminized. It is important, incidentally, that such a mirror be not touched with the fingers nor cleaned by ordinary methods, because the aluminum surface is easily marred. While the projected image may not be perfectly sharp to the very edges of the screen, a sufficient area of the specimen is covered by the 10x lens so it is amply large to be seen from an appreciable distance by several observers. The distance from the screen to the lens is approximately 35 inches, and from the lens to the specimen about 1-inch. These dimensions give a magnification of approximately 35x. A type T-10, 200-watt projection lamp within a suitable housing provides adequate illumination even where there is considerable extraneous light. No condensing lenses are necessary since the concave mirror of the microscope serves the dual purpose of condensing and, at the same time, directing the light upward through the specimen and lens. The projector housing is constructed of plywood and is painted a flat black inside. The mirror is further protected from dust by having the aluminized surface downward. Provision is made for easy removal of the microscope and the viewing screen for cleaning. The whole should be mounted on a steady support to minimize vibration.

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While the idea is not new and originality for it cannot be claimed, the projectoscope was used very frequently this past campaign, being placed on the pan floor where it was readily accessible for examination of sugars, massecuites, and syrups, and several operators have expressed the opinion that it has been of considerable value to them in sugar end control.

The outstanding advantage of such a device is that it provides visual inspection by a group rather than by only one person at a time; defects and irregularities of sugar end products are pointed out and seen simultaneously by all observers. This, of course, cannot be accomplished with the ordinary magnifier or microscope.

Due credit must be given J. B. McDonald for his suggestion of the application of the principles of the device in our industry and to Ivan E. Enwall for his assistance in the designing and building of the instrument.

Beet Laboratory Pulp Mixer

PAUL M. SMITH[1]

In a beet testing laboratory where a great number of individual samples of beets are tested for sugar content each day, it is necessary for greatest accuracy, that the pulp samples produced by the rasp be thoroughly mixed before analysis. Primarily because of this fact and also because the mixing of these samples by hand is very laborious and the quality of mixing is questionable at times, it was decided to design a machine which would eliminate to a considerable degree the labor as well as the human element involved. The following is a description of the machines which have proved highly successful in our beet laboratories during the past three campaigns.

To a 3-inch fiber pulley is attached a steel spur pinion which drives two brass gears. The gears are attached to 5/16-inch shafts, running vertically in bronze bearings fitted with Zerk grease fittings. On the opposite ends of the shafts are two ¾-inch hubs counter bored for 5/16-inch shafts. The two beaters are 4 inches across and 4 inches long and are constructed of No. 8 brass spring wire formed into a horseshoe shape. The wires are held in cross-bars, made of ½-inch key steel, by safety set-screws. A ¼-inch shaft attached to each pair of cross-bars is inserted in the ¾-inch hubs and is held by a set-screw. The bearing assemblies are held, by means of a ⅜-inch cap screw, between two pieces of ½-inch by 3-inch flat iron on one of

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which is mounted the driving motor. A sheet metal safety guard covers pulley and gears. The mixer is driven by a 1/20 h. p. constant-speed motor. The approximate speeds are: Motor 1,750 r.p.m.; beaters 300 r.p.m.

The mixer is mounted in a position convenient to the operator, at such a height that will permit manipulation of the mixing bowl while the sample is being mixed, and runs continuously. A light sheet metal guard around the beaters to catch the small quantity of pulp thrown off the beaters between samples is desirable.

In operation the mixing bowl containing the sample of pulp is held in the hands of the operator and moved about so that all parts of the bowl's contents are reached by the beaters until thorough mixing is obtained. The average size sample of pulp from 25 to 30 pounds of beets is completely mixed in about 15 seconds. The quality of the mixing can be checked by adding a small quantity of red ink to a sample of pulp and observing the distribution of the dye during the mixing.

With this device an operator is able to mix many hundreds of samples of pulp per shift and the fatigue of operators and the uncertainty of proper mixing by hand methods are eliminated, thus speeding up the work and increasing the accuracy of the tests.

A Polariscope Printer

C. R. KOONTZ[1]

About 3 years ago D. J. Roach, assistant general manager, and S. J. Osborn, general chemist, both of the Great Western Sugar Company, suggested that a polariscope that would print the sugar reading directly on the analysis ticket would avoid errors in reading the vernier scale and in transferring the reading to the analysis ticket.

The vernier scale is similar to scales used on most scientific instruments. It involves the reading of numbers and the counting of lines or divisions. Most scales read in one-tenth of a whole number. Experienced operators can read exactly to one-tenth and estimate to five-hundredths or less. Inexperienced operators sometimes have difficulty reading to one-tenth of a division.

The operation of reading a polariscope consists of placing a prepared sample in the instrument, then looking into the lower, or field, eyepiece where a circular field of light divided into halves by a vertical line is seen. These two halves are different in shade or color. By turning the reading screw which is located below the eyepiece, the operator moves a quartz wedge across the optical system. When this wedge is brought into the proper position, the two halves of the colored field have the same intensity and shade. At this point the vernier scale reads the percentage sugar in the sample under observation. The vernier scale is then read through the upper eyepiece or telescope. It takes longer and requires more experience to read this scale than it does to match the colors in the field. Most errors of analysis are made in reading this vernier scale and copying the reading on the analysis ticket.

Having these ideas in mind we made an experimental instrument which was used in the Beet Laboratory during the complete season and proved satisfactory. The original instrument was very similar to the present one except that it had a hand printing device.

The present instrument consists of a printing wheel carrying an etched brass scale reading in one-tenth sugar degrees. It covers a range from 7 to 25 percent sugar. The printing wheel is mounted in bearings directly under the reading screw. This reading screw operates the quartz compensating wedge to match the colors of the field and moves the vernier scale to the proper sugar reading. The printing wheel is attached rigidly to the reading screw so that any movement of the vernier scale results in a proportional rotation of the printing wheel. Most of the polariscopes now in use pass through 52

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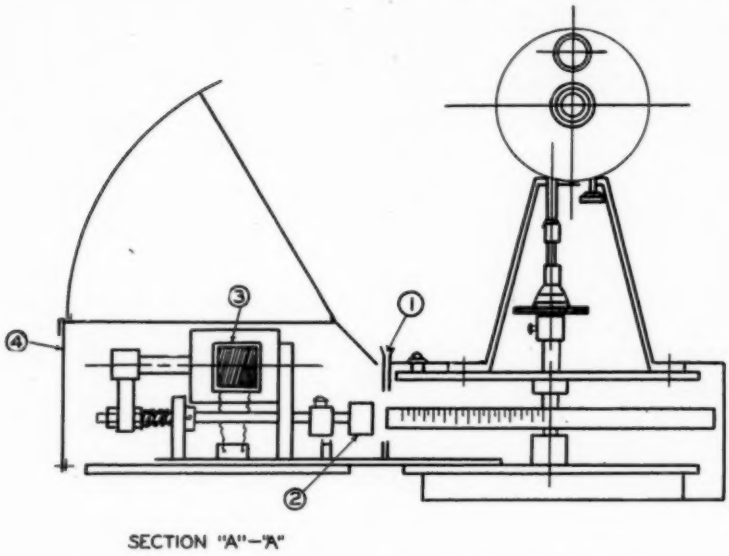

Figure 1.—1, card holder; 2, printing hammer; 3, solenoid; 4, cover.

to 56 sugar degrees for one complete revolution of the reading screw. In fitting a printing scale to an individual polariscope a standard scale is used, all scales having 1/16-inch divisions for each one-tenth sugar degree. The scale is adapted to the individual vernier scale by varying the diameter of the printing wheel. For example a scale is to be fitted to an instrument having 52 sugar degrees for one complete revolution of the reading screw. Since our printing divisions are 10/16 of an inch for each sugar degree, a complete revolution of the wheel would be 520/16, or the circumference of the printing wheel with scale would be 32.5 inches corresponding to a diameter of 10.345 inches. It is possible to fit the standard scale to any vernier scale as long as the vernier scale is uniform. There is a fine adjustment on the coupling fastening the reading screw to the printing wheel by which the vernier scale can be set exactly with the printing scale. The rack which moves the vernier scale is double and when properly adjusted has no back-lash; therefore the printing scale operates in exact relationship with the vernier scale.

The printing device is powered by an electric solenoid operating on 110 volts AC. This is shown in the accompanying drawing. A typewriter ribbon is moved between the printing scale and the card holder. A printing hammer strikes the card, driving it against the

printing scale and a fixed index point. The printed card can easily be read to five-hundredths of a sugar degree.

One of these instruments has been in use in our Beet Laboratory for two seasons. Two more were used last season. They have given satisfaction and have received favorable comment from the Growers' Association and the cashier's department. We expect to equip several more of our beet laboratories with them this year.

The printer has the following advantages over the regular polariscope.

(1) It is relatively simple to teach a new operator to match the colors of the polariscope field, but it takes much more time to teach one to read the vernier scale without error.

(2) It is necessary only to place the analysis ticket in the printer slot, match the colors of the field, and press a button. The sugar reading is printed directly on the analysis ticket. This eliminates the reading of the vernier scale. This saves time and eyestrain for the operator. It relieves the operator of writing the reading on the ticket and thus eliminates errors in transposing figures.

(3) The cashier carries the figures to the nearest one-tenth. Formerly it was necessary for the polariscope reader to decide whether the reading should be the next tenth higher or the next tenth lower. The divisions on the ticket being 1/16″ apart makes this very easy to decide, and the cashier's office makes the decision.

(4) It leaves a permanent record on the analysis ticket for the inspection of anyone interested.

Acknowledgment is given to:

S. J. Osborn, general chemist, for many helpful suggestions and encouragement;

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Evaluation of Factor For Conductance of Water in Presence of Sugar

F. R. Calton, F. W. Weitz, and Elmer Calender[1]

Introduction

The conductivity of sugar solutions is generally recognized as a quick method of estimating the ash content of sugars. In its simplest form a relationship, called the "C-ratio", is established between the sulfated ash less 10 percent and the electrical conductivity. The sulfated ash and electrical conductivity are determined for a number of representative samples and the quotient of the sulfated ash less 10 percent divided by the specific conductance is termed the C-ratio. For beet sugars Lange (*2*)[2] proposed the use of solutions having a concentration of 5 g in 100 ml. His studies indicated that the C-ratio of German beet sugars slowly increased; but up to a concentration of about 1 percent ash (sulfated ash less 10 percent) he found a nearly constant average ratio equal to 1786. Hence, by multiplying the conductance in reciprocal ohms by the C-ratio value of 1786, he arrived directly at the ash value. While Lange's value is admittedly not representative of the C-ratios for all beet sugars, it does give a useful estimate of the ash for most beet sugars.

Conductance, as measured on a sugar solution, is a composite of a number of varying influences; e. g., conductivity of the water used in preparing the solution, concentration of the solution, nature of the ash constituents, and effect of the non-electrolyte (sugar) on the conductivity of the water, and of the ash constituents. Most of these variables are held constant by the use of a single concentration of sugar (5 g in 100 ml) or are constant by postulate if one accepts the C-ratio value of 1786 as given by Lange. Under his conditions the relation simplifies down to the following:

$$LA = Ls - fLw$$

$$\% \text{ Ash} = La \times 1786 \times 10^{-6}$$

where LA = specific conductance of the ash constituents in the sugar; Ls = specific conductance of the sugar solution; Lw = specific conductance of the water used in preparing the sugar solution; f = a factor converting the conductance of water to its conductance in the presence of 5 g sugar / 100 ml; 1786 is Lange's evaluation of the C-ratio. Ash is expressed in terms of sulfated ash less 10 percent and specific conductance in terms of reciprocal megohms.

The correction factor, f, has been evaluated for these conditions by Lange (*2*), Toedt (*3*) and others with generally agreeing results

[1]Chief Chemist, Oxnard Factory, General Chemist and Chief Chemist, Mason City Factory, respectively, American Crystal Sugar Company, Denver, Colo.

[2]Italic numbers in parentheses refer to literature cited.

of about 0.9. Zerban and Sattler (*4*), working with cane sugars, also give data from which f can be calculated as a variable which approaches 0.9 in the range of low conductance water. Such a result is equivalent to a value for a of approximately 0.03 in the fundamental formula of Arrhenius (*1*). His formula is $K=Ko(1-a\ P/2)^2$, where K is the specific conductance of a solution to which P volume percent of a non-electrolyte has been added, Ko is the specific conductance of the aqueous salt solution and a is a constant whose value depends on the nature and concentration of the electrolytes and non-electrolytes. For a sucrose solution of 5 g/100 ml the volume concentration (weight divided by specific gravity) is 5/1.59 or 3.15 percent. Especially significant in the work of these investigators is the fact that in all cases the ash content was very high, on the order of 10 to 100 times that prevailing in a solution of granulated beet sugar (5 g/100 ml) where the ash rarely runs over 0.020 percent on sugar.

The American Crystal Sugar Company has been estimating sulfated ash less 10 percent in granulated sugars from conductivity measurements by the use of Lange's factor for a number of years with generally satisfactory results. To correct the conductivity of the water to its conductance in the presence of 5g of sucrose / 100 ml a factor of 0.91 was used, which is the generally accepted value. For some time, however, it has been common knowledge amongst technicians in the Company laboratories that a lower ash value would be calculated if the sugar were dissolved in a water of high conductance, say 10 reciprocal megohms, than if it were dissolved in a water of low conductance, say 1 or 2 reciprocal megohms. Accordingly, it was decided to investigate the factor under the conditions dominant in our tests, i. e., water having conductance in the range of 1 to 10 reciprocal megohms and granulated beet sugar with ash values under 0.020 percent.

Procedure

A brief survey of the literature showed that previous investigators had all followed essentially the same pattern. As detailed by Lange (*2*), a molasses solution was prepared and to this was added various quantities of a purified sugar. The value of Ko was determined for the original molasses solution and K for each of the solutions with added sugar. From these and the weight of sugar in the solution it was a simple matter to calculate the factor, f.

We chose to depart from this procedure in favor of what appears to be a more direct approach. In this we take advantage of the fact that the equation $LA = Ls - fLw$ is that of a straight line having a slope f. Accordingly, if one should hold LA constant by using a single sugar and then vary the conductance of the water, the conductance of the solution should be a direct function of the

conductance of the water.

In the work reported here two analysts working in different laboratories carried out similar tests, each using three different sugars, a total of six sugars, with ash contents ranging from about .020 down to .005. In both laboratories, Oxnard and Mason City, a series of waters was prepared such that their specific conductances covered a range of about 8 down to 1 reciprocal megohms (125,000 to 1,000,000 ohms). At Oxnard five waters were used and at Mason City eight waters. Each of the three sugars were dissolved in the various waters (5 g in 100 ml) and the conductivities of the solutions and the waters carefully determined at temperatures close to 20.0° C. The tests were repeated on successive days, giving 23 determinations for each sugar at Oxnard and 24 for each at Mason City.

Table 1.—Specific conductances* of water and sugar solutions, Oxnard laboratory.

Sugar	A		B		C	
Specific conductance	Lw	Ls	Lw	Ls	Lw	Ls
	1.37	4.36	1.37	7.10	1.37	12.2
	1.38	4.27	1.38	6.94	1.38	12.0
Day 1	2.43	5.07	2.43	7.71	2.43	12.8
	4.18	6.40	4.18	9.05	4.18	14.1
	5.44	7.48	5.44	10.20	4.27	14.3
	2.71	5.33	1.40	6.99	2.71	13.0
	3.10	5.82	2.71	8.17	3.10	13.3
Day 2	3.34	5.61	3.10	8.31	3.20	13.2
	4.27	6.42	4.27	9.10	5.44	15.0
	7.51	9.37	7.51	11.90	7.51	17.0
	1.40	4.28	2.53	7.82	1.40	12.0
	2.53	5.17	3.20	8.39	2.53	12.8
Day 3	3.92	6.21	3.34	8.38	3.92	13.8
	4.14	6.37	4.14	9.07	4.14	14.0
	6.03	7.88	6.03	10.56	6.03	15.5
	2.54	5.11	2.54	7.88	1.40	12.1
	3.20	5.41	3.92	8.80	3.15	13.3
Day 4	4.30	6.52	4.30	9.19	3.33	13.6
	5.28	7.22	5.28	9.90	3.34	13.3
	6.44	8.22	6.44	10.80	5.28	15.0
	1.40	4.19	1.40	6.98	2.54	13.0
Day 5	3.15	5.39	3.15	8.18	4.30	14.4
	3.33	5.66	3.33	8.48	6.44	16.1

*Reciprocal megohms at 20.0° C.

Apparatus

The apparatus used at both laboratories consisted of the No. 4961 Leeds and Northrup Sugar Ash Bridge and the No. 4924 Leeds and Northrup Conductivity Cell. The ash bridge is a portable conductivity indicator with an alternating current galvanometer incorpor-

ated in it. A circular slide wire has its scale directly calibrated in terms of conductance in reciprocal megohms. A built-in temperature compensator was used to correct observed conductances for the few tenths of a degree by which the solutions varied from the standard temperature of 20.0° C. This instrument also has a cell-constant compensator so that all readings were obtained directly as specific conductances in reciprocal megohms at 20.0° C.

Data

The data are tabulated in tables 1 and 2. At Oxnard no effort was made to use the same waters from day to day or even for all three sugars on the same day. Accordingly, the specific conductance of water is shown corresponding to each solution tested. At Mason City, on the other hand, eight waters were prepared in large enough amounts so that three complete series of tests could be made. As a result only one value for water is shown opposite tests on a group of the three sugars.

Evaluation of the Factor

The data in tables 1 and 2 were summarized by the method of least squares into equations for six straight lines, one for each sugar.

Table 2.—Specific conductances* of water and sugar solutions, Mason City Laboratory.

Sugar		D	E	F
Specific conductance	Lw	Ls	Ls	Ls
	.97	4.47	6.43	9.67
	1.78	5.05	7.04	10.23
	2.93	5.90	7.86	11.24
	3.87	6.54	8.45	11.67
Day 1	4.52	7.05	8.92	12.30
	5.63	7.96	9.72	13.00
	6.74	8.85	10.70	14.00
	8.07	9.98	11.72	15.10
	.95	4.48	6.44	9.65
	1.75	5.04	6.92	10.21
	2.91	5.86	7.84	11.16
Day 2	3.84	6.53	8.48	11.70
	4.49	7.04	8.94	12.20
	5.59	7.87	9.72	13.00
	6.68	8.88	10.73	14.00
	8.04	9.98	11.73	15.20
	.91	4.42	6.39	9.62
	1.64	4.97	6.88	10.14
	2.92	5.88	7.87	11.14
	3.85	6.54	8.52	11.66
Day 3	4.46	7.03	8.86	12.20
	5.58	7.90	9.73	12.90
	6.66	8.87	10.67	13.90
	8.03	10.01	11.74	15.10

*Reciprocal megohms at 20.0° C.

The actual manipulation of the data will not be described here since the least squares method is the accepted method for evaluating a line of best fit. Table 3 and the accompanying graph summarizes these lines of best fit as well as other information useful in judging the goodness of fit.

Inspection of table 3 shows that in the general equation Ls=LA+fLw the value of f varies from a low of 0.746 to a high of 0.799 for sugars ranging from a specific conductance of 10.9 down to 3.1 reciprocal megohms (.0195 to .0055 calculated ash). By having the work done at different laboratories by different technicians it was hoped that any important difference in technic or apparatus which might effect the value of the factor would be indicated. Inspection of the data does not indicate such a difference; for, even though the factors evaluated from Mason City data are slightly lower than those based on Oxnard data, the differences do not appear significant. Important also in judging the usefulness of the factors is information concerning how well the data fit the calculated line. The coefficient of correlation, r, and the measure of scatter about the line SLs, shown also in table 3, both indicate high degrees of fit in all cases. Further, in plotting the data no evidence of curvature was indicated. From these considerations it would appear that the average value of 0.773 is closer to the true value of the correction factor for the conductance of water in the presence of 5 g/100 ml of granulated beet sugar at 20° C. than values previously reported.

Table 3.

Instrument	Line of best fit	r	SLs	LA	Ash	f
		Low ash sugars				
Oxnard	Ls= 3.093+.799Lw	.995	.132	3.093	.0055	.799
Mason City	Ls= 3.634+.777Lw	.999	.053	3.634	.0065	.777
		Medium ash sugars				
Oxnard	Ls= 5.881+.775Lw	.995	.128	5.881	.0105	.775
Mason City	Ls= 5.650+.746Lw	.999	.076	5.650	.0101	.746
		High ash sugars				
Oxnard	Ls=10.894+.782Lw	.990	.183	10.894	.0195	.782
Mason City	Ls= 8.865+.761Lw	.999	.055	8.865	.0158	.761

Note: Sugars used at Oxnard were not the same as those used at Mason City. Average value of factor, f=.773.

Formulae

Ls=LA+fLw

Ash=LAx1786x10-6

Nomenclature

Ls=Specific conductance of the solution.

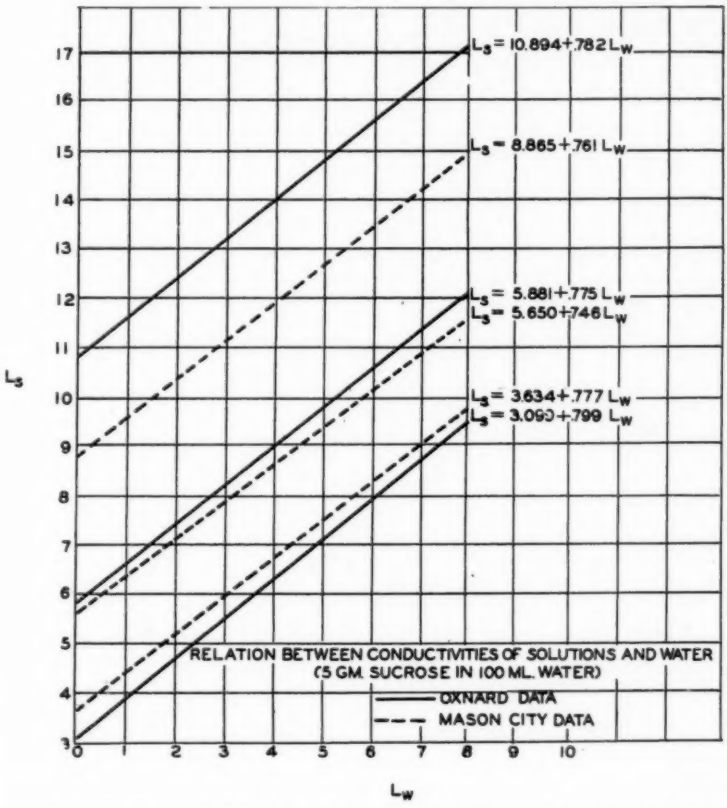
LA=Specific coductance of the sugar.

Lw=Specific conductance of the water.

f=A factor correcting the conductance of water for the effect of sugar.

r=Coefficient of correlation, a measure of the goodness of fit.

SLs=Measure of scatter about the line.



Substitution of 0.773 in the Arrhenius equation now gives a value for a of .077 as compared with previously reported values approximating .03. This is not so surprising, however, when it is considered that the older value was obtained on solutions of very much higher ash content than would be present in solutions of granulated beet sugars of today.

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Some Details of the Hot Water Digestion Method For the Determination of Sugar in Cossettes

S. J. Osborn[1]

Credit is due to Pellet (*13*)[2] for championing the method of hot water digestion which is usually given his name and which is the generally accepted method in all countries for determining the percentage of sugar in cossettes. The purpose of this paper is to present, in summarized form, a description of some of the details which have been found to be important.

Preparation of Sample.—Cossette samples are usually ground in some kind of meat chopper. This allows a large sample to be ground rapidly to a fineness sufficient to secure a well mixed sample suitable for analysis by hot water digestion.

Concentration.—The use of half-normal (26 grams of ground beets per 200 ml. of solution) concentration is general. The use of full normal concentration is not advisable because the proportion of pulp to liquid is so great that there is risk of incomplete diffusion. With the use of half-normal concentration the reading of the filtrate in a 400-mm. tube gives directly the percentage of sugar.

Temperature of Digestion.—Variations of temperature seem to be unimportant, at least within reasonable limits. A bath temperature of 80° C., which insures complete diffusion after 30 minutes immersion of the digestion flask, is generally standard. There is nothing gained by using any higher temperature.

Supplementary Digestion.—In the digestion as first practiced the flask was filled about two-thirds full, and the volume was completed after cooling. Weisberg (*16*) pointed out that under this condition results were too low on account of incomplete equalization of concentration in the surrounding liquid with that of the liquid in the cells of the pulp. This error was found to increase, as would be expected, with increased coarseness of pulp.

It is advantageous to carry out the principal digestion with an incompletely filled flask, both to allow air bubbles to escape readily and to permit the contents to be mixed by swirling at intervals during the digestion. Weisberg accordingly prescribed a supplementary digestion, now generally standard, which involves completing the volume approximately to the mark with hot water and then digesting for

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[1]General Chemist, Great Western Sugar Company, Denver, Colo.

[2]Italic numbers in parentheses refer to literature cited.

10 minutes longer. After cooling, the necessary small amount of water is added to complete the final exact volume.

Evacuation to Remove Air.—Not always recognized is the error caused by the presence in the ground pulp of air which may not be completely removed during digestion. This causes high results because the true volume of liquid is less than 200 ml. if air is present.

Any one who has tried to run a hot water digestion on finely rasped pulp produced by a Keil disc knows that results are as much as 0.5 percent high if the air occluded in large amounts in the pulp is not removed.

Although the amount of occluded air in cossettes which have been reduced to a pulp in a meat chopper is much less than in rasped pulp, it is sufficient to produce a definite error in the Pellet digestion method, at least under some conditions. We have found differences, with and without the removal of air, varying from .03 when the flask was shaken four times during the digestion up to .12 (in one case .15) when the flask was not shaken at all.

The air bubbles can largely be removed by evacuation and the best time to do this is after the normal weight of cossettes has been rinsed into the flask with water, with the use of about 100 ml., so that the flask will be only half full. This allows room for the bubbles to break without loss of liquid.

Another great advantage of the removal of the air is that the particles of pulp tend to sink instead of float, and at the end of the digestion the solution is so free from foam that it can usually be made up to the mark accurately without the use of ether to break the foam.

Because the removal of air is in every way advantageous, it should be a part of the standard hot water digestion method.

Volume Allowance for Marc.—In the volumetric method it is customary to use a flask graduated at a volume which will exceed 200 ml. by the amount considered to represent the proper allowance for the marc and lead precipitate. Investigators of various countries have reported a great amount of work on the subject (*3*) which is too extensive to permit any review in this paper. It is important that the volume of the lead precipitate, at one time neglected, be taken into consideration as well as the volume of the marc.

Although there is no complete agreement on a standard volume allowance for marc and lead precipitate, and possibly there should not be because of variation of beets in different localities, it is now generally believed that the old figure of 0.6 ml. (for the volume occupied by the marc and lead precipitate from 26 grams of beets) is too low.

The preponderance of opinion now favors a value of 1.0 ml., but some believe it to be 1.5 ml., or a little more.

As our own results (*11*, *12*) have indicated a value of 1.0 ml., we graduate the cossette flask at 201.0 ml.

Adsorptive Effects of Marc.—One other feature in connection with marc needs consideration—its possible influence on polarization caused by its adsorptive power. Some investigators (*3*) claim that marc adsorbs water, the so-called "colloid water" or "water of imbibition," and that results are therefore too high on account of the increased volume of "marc hydrate" and the decreased volume of solution.

On the other hand Mintz et al. (*10*) and Martraire (*9*) claim that marc adsorbs sugar and thereby causes low results.

Obviously we cannot say that results are high on account of adsorbed water and that they are at the same time low on account of adsorbed sugar. We have to make some choice or, at any rate if both effects exist, the important point is which one predominates.

Some of our own work, which is submitted with no finality, confirms in at least some degree the effect found by Martraire. We repeated his procedure, consisting of a series of cossette digestions to each of which a weighed amount of sugar was added (approximately enough to double the polarization), and a parallel series made without the addition of sugar, all tests being made in duplicate. The difference in polarization was compared to that calculated as equivalent to the added sugar (table 1).

Our results, in agreement with those of Martraire (*9*) and also of Bonnet (*2*), show no determinable adsorptive effect for finely divided, rasped pulp, but with pulp ground in a meat chopper there was a distinct failure to "recover" the added sugar by .09 percent on beets in one series and .05 percent in another. This indicates that with coarsely ground pulp an adsorptive effect exists, but no one seems to be able to figure out exactly to what extent the polarization of the original cossettes is affected.

Martraire says that meat choppers, which give a coarse pulp, should not be used for the analysis of beets. However, the writer knows of no machine which will satisfactorily reduce a cossette sample of several pounds, a desirable size, to fine pulp in a reasonable length of time.

This question can probably be further studied to advantage.

Use of Acetic Acid.—The addition of one or several drops of acetic acid just before the solution is polarized is recommended in

Table 1.—Polarization effect of sugar added to hot water digestions, campaign 1936-37.

Reported by	Kind of pulp	Percentage sugar by hot digestion	g Sugar added	Pol. of digestion with added sugar		Loss of polarization attributed to adsorption
				Calcd.	Actual	
Bair	Rasped	15.22	3.9	30.22	30.20	.02
Bair	Rasped	14.32	3.9	29.32	29.30	.02
Bair	Rasped	17.40	3.9	32.40	32.40	.00
					Avg.	.013
Hartman	Rasped	19.00	4.0	34.38	34.35	.03
Hartman	Rasped	17.05	4.0	32.43	32.45	−.02
					Avg.	.005
Bair	Meat chopper	16.25	3.9	31.25	31.15	.10
Bair	Meat chopper	15.55	3.9	30.55	30.50	.05
Bair	Meat chopper	15.75	3.9	30.75	30.70	.05
Bair	Meat chopper	16.45	3.9	31.45	31.40	.05
Bair	Meat chopper	15.55	3.9	30.55	30.55	.00
Bair	Meat chopper	16.00	3.9	31.00	30.85	.15
Bair	Meat chopper	15.95	3.9	30.95	30.88	.07
Bair	Meat chopper	14.90	3.9	29.90	29.75	.15
Bair	Meat chopper	15.15	3.9	30.15	29.95	.20
					Avg.	.09
Hartman	Meat chopper	15.45	4.5	32.76	32.60	.16
Hartman	Meat chopper	15.25	4.7	33.33	33.30	.03
Hartman	Meat chopper	15.55	4.1	31.32	31.35	−.03
Hartman	Meat chopper	16.28	4.5	33.59	33.40	.19
Hartman	Meat chopper	16.27	4.5	33.58	33.52	.06
Hartman	Meat chopper	15.30	4.6	32.99	32.80	.19
Hartman	Meat chopper	15.45	4.02	30.91	30.75	.16
Hartman	Meat chopper	14.45	4.2	30.60	30.78	−.18
Hartman	Meat chopper	16.12	4.5	33.43	33.55	−.12
					Avg.	.05

some methods. The purpose evidently is either to prevent the formation of lead fructosate (*4*) or to correct the effect of lead subacetate on the polarizing power of asparagine (*5*).

We have made a number of tests with and without the addition of various amounts of acetic acid without finding any difference in polarization. We have therefore not included the use of acetic acid in our method.

From the standpoint of pH it may be noted that lead subacetate is not so alkaline as is commonly supposed. The standard solution, of density 55° Brix, is a 6.6 pH determined electrometrically. (Colorimetric determination shows a wide difference, viz., 7.5 pH.) We

have found "digestion juice" in the absence of lead subacetate to be within the range of about 6.0-6.8 pH and to be *but little* affected in pH by the addition of lead subacetate. The use of a little acetic acid could hardly be expected to make much change in pH.

Destructible Polarization.—Stanek and Vondrak (*14*) have made an interesting contribution to cossette analysis in their method for determining "destructible polarization." They measure the change (usually a decrease) in polarization produced by heating digestion juice made alkaline with sodium hydroxide, this being considered to correspond to the change in the polarization of non-sugars produced by the action of lime in the factory carbonation process. The procedure is somewhat involved and is more suited to special investigations rather than as a routine method in the determination of sugar in cossettes.

We have made many determinations of destructible polarization at various times and on various conditions of beets. These have quite uniformly shown values of 0.1 to 0.2, beets of the best quality having shown the former value, or sometimes slightly less. We have not been successful in explaining high unaccountable losses by the presence of high destructible polarization in beets. In these respects our results have confirmed those of Stanek and Vondrak.

Addition of Lead Subacetate Before vs. After Digestion.—When the method of hot water digestion was first developed, the basic lead acetate reagent was added after digesting and cooling. When it was found that the reagent could be added before digestion without apparently affecting the results, this procedure then became customary because it was thought that, by precipitating impurities at the start, the extraction of the sugar and the clarification of the solution were facilitated.

During a campaign when the beets were abnormal and unaccountable losses were unusually high, Le Docte (*8*) reinvestigated this question. He found the results by hot water digestion, when the lead acetate was added *after* digestion, agreed with those obtained by cold water digestion, but, if the lead was added *before* digestion as was then customary, the hot water results might, in case of thawed and unsound beets, be much higher. This he attributed to the invert sugar present, on the ground that the levulose component would be rapidly attacked during digestion by the PbO of the basic lead acetate, while the dextrose would be unaffected, thus giving too high a polarization.

Le Docte's theory appeared plausible as far as it went, and we have at various times investigated the same question. Our work has involved on the one hand the behavior of cossette digestions to which

small amounts of invert sugar had been added, and on the other hand comparative determinations on cossette samples.

The results given in table 2 are typical. The amount of added invert sugar corresponds to the maximum amount that we have found in factory cossette samples—about 4 percent on dry substance.

These results offer strong confirmation of the Le Docte theory. It will be noted that the amount of added invert sugar is not enough to affect the polarization to a marked degree when the lead is added after digestion (compare 1 b and 2 b of table 2), but digestion in the presence of basic lead acetate of the solutions containing the added invert sugar elevates the polarization to the extent of about +.30°. This happens to be just what the increase of polarization (rotation of 0.1 gram of dextrose) would theoretically be if the levulose were destroyed by digestion in the presence of basic lead acetate and the dextrose component of the invert sugar were left unaltered.

Invert sugare (both the dextrose and levulose) is completely destroyed by heating with strong alkalies. With milder alkali treatment levulose is more readily attacked than dextrose. Digestion with basic lead might therefore be expected to have a preferential destructive action on levulose. However, in view of the large effects found with little change in pH, it seems probable that some specific action of lead subacetate on the levorotation of levulose is involved. Lobry de Bruyn and van Ekenstein (*6*) and Schneller (*6*) are reported to have observed such an effect. Stanek and Vondrak (*15*) found that heating of digestion juice containing added invert sugar in the pres-

Table 2.—Effect of added invert sugar in cossette digestions.

	Brighton		
	Early in campn.	Jan. 8 1931	Jan. 15 1931
Campaign 1930-31			
1. Polarization determined:			
(a) Adding lead before digestion	15.30	15.62	15.55
(b) Adding lead after digestion	15.40	15.65	15.59
2. Same as 1, adding 0.2 gram invert sugar (in form of the calculated amount of the prepared solution) to 26 g of cossettes in a 201 ml. flask, before digestion and lead addition. Polarizations:			
(a) Adding lead before digestion	15.60	16.00	15.85
(b) Adding lead after digestion	15.35	15.60	15.60
Campaign 1931-32	Billings	Lovell	Lovell
3. (a) Same as 1 (a) above	16.62	19.13	18.30
(b) Same as 1 (b) above	16.68	....	....
4. (a) Same as 2 (a) above	16.92	19.30	18.52
(b) Same as 2 (b) above	16.68	19.03	18.22

ence of lead subacetate caused a plus polarization with little change in the copper-reducing power.

We have made many hundred determinations on factory cossettes comparing the addition of lead before and after digestion. With normal beets there is no determinable difference. With deteriorated beets there is often a difference of as much as 0.2 percent sugar, the polarization being lower when the lead is added after digestion. On individually selected rotten beets still greater differences have been obtained. There is evidence that the difference tends to increase with progress of the campaign as deterioration of stored beets takes place.

Fortunately then the point is not of importance for normal beets on which most determinations of sugar are made, and in such cases the lead may be added either before or after digestion. However, since there is evidence that the presence of lead during digestion causes a false plus polarization in deteriorated beets containing invert sugar, it is the opinion of the writer that the results under such conditions are more accurate when the lead is added after digestion, and this procedure has been incorporated in our standard method of analysis.

There is one other point in this connection that may deserve consideration: Whether any destruction of sucrose by inversion may take place under the conditions of the hot water digestion. Since it has been pointed out that the pH of the digestion juice is little affected by the addition of lead subacetate, the question is almost equally pertinent whether the lead is added before or after digestion. At 6.0 pH, which according to our experience is probably the usual lower limit of a cossette digestion, the destruction of sucrose in 40 minutes at 80° should not exceed .01 percent on beets. It is still possible that the effect might exist in measurable amount in the case of badly deteriorated beets.

If the point is important, it can readily be taken account of by adding 0.1-0.2 gram of calcium carbonate to the digestion before heating. Enough of this will go into solution to raise the pH almost to 7 or slightly above, but the amount undissolved will not noticeably affect the volume when the solution is made to the mark. We have made many tests with and without the use of calcium carbonate, but, since we have never found any difference in results, we have not incorporated its use into our method.

Bachler, who omitted the lead addition in order to obtain an unclarified digestion juice for the determination of refractometer dry substance, has said (*1*): "From many hundreds of control tests we

know that no appreciable destruction of sucrose occurs during the digestion without lead acetate."

It also occurred to the writer to investigate whether the addition of lead subacetate after digestion causes any difference in the volume of marc and lead precipitate, all tests previously reported having been made with the addition of lead before digestion (*11*, *12*). Determinations by the Brown method (*11*) are reported in table 3. The hot digestions show a slightly lower average value when the lead is added after digestion, although the difference is small and hardly significant. The results incidentally confirm the value of 1.0 ml.

Table 3.—Determinations of the volume of marc and lead precipitate, campaign 1933-34.

Test No.	Percentage sugar	Lead addition	Material	Volume of ppt. in milliliters calculated to 26 grams
1	15.3	Before	Cossettes, hot digestion	.96
2	14.9	Before	Cossettes, hot digestion	.94
3	17.9	Before	Cossettes, hot digestion	.98
4 a	16.0	Before	Cossettes, hot digestion	.96
4 b	16.0	After	Cossettes, hot digestion	.90
5 a	14.8	Before	Cossettes, hot digestion	.92
5 b	14.8	After	Cossettes, hot digestion	.90
6 a	15.4	After	Cossettes, hot digestion	.90
6 b	15.4	After	Cossettes, hot digestion	.94
6 c	15.4	After	Cossettes, hot digestion	.92
		Average, lead before digestion		.95
		Average, lead after digestion		.91
7	18.1	Before	Rasped pulp, cold digestion	.88
8	15.8	Before	Ralped pulp, cold digestion	.78
9 a	17.0	Before	Rasped pulp, cold digestion	.78
9 b	17.0	Before	Rasped pulp, cold digestion	.76
10 a	17.5	Before	Rasped pulp, cold digestion	.80
10 b	17.5	Before	Rasped pulp, cold digestion	.82
11 a	16.8	Before	Rasped pulp, cold digestion	.74
11 b	16.8	Before	Rasped pulp, cold digestion	.62
12	16.4	Before	Rasped pulp, cold digestion	.74
		Average		.77
13	17.5	After	Rasped pulp, hot digestion	.98
14 a	17.0	After	Rasped pulp, hot digestion	.92
14 b	17.0	After	Rasped pulp, hot digestion	.90
15	18.1	Before	Rasped pulp, hot digestion	.92
16	15.8	Before	Rasped pulp, hot digestion	.88
17 a	16.4	Before	Rasped pulp, hot digestion	1.04
17 b	16.4	Before	Rasped pulp, hot digestion	1.07
		Average, lead before digestion		.98
		Average, lead after digestion		.93

previously established (*11*, *12*). It is of interest that the determinations by cold water digestion are distinctly lower; this may deserve consideration in the cold water method, with which this paper is not concerned.

Hot Water Digestion Method of the Great Western Sugar Company.—The detailed procedure of the Great Western Sugar Company is on record elsewhere (*7*).

Summary

Various details of the hot water digestion method for the determination of sugar in cossettes have been discussed. The supplementary digestion to equalize concentrations, evacuation to remove air, and addition of the lead subacetate after digestion are recommended as standard procedure. Some questions are not finally resolved.

Acknowledgment

For numerous investigations, the results of which are described in this paper largely in summarized form, the writer is indebted to many chemists of the Great Western Sugar Company, particularly to C. B. Millen for his investigations on the effect of invert sugar, to G. E. Stevens for establishing the effect of removing air by evacuation, to J. A. Bair for the mare determinations reported in this paper, and to J. A. Bair and V. V. Hartman for their work on the polarization effect of sugar added to hot water digestions.

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Kinetics of Sucrose Crystallization: Mechanism of the Reaction in Real Massecuites[1]

ANDREW VAN HOOK[2]

Although the activity interpretation of sucrose crystallization, already sucessfully applied to pure sucrose solutions and synthetic massesuites (*11*)[3], does not require any mechanical or molecular model, it does imply (*11d*) an independence of any structural nature or transport behavior in the operating medium. It is therefore necessary to establish this suggested independence to warrant continued application of the activity theory to the ultimate practical goal of pan boiling and crystallization. It has been demonstrated with pure sucrose solution, and intimated for impure syrups (*11c*), that crystallization rates are determined by some interfacial reaction rather than an interboundary one. That is, as frequently suggested in sugar literature but often overlooked, diffusion and viscosity are not primary rate controlling factors in the crystallization of sucrose. It is the intention of this paper to examine the role of diffusion and the reciprocally related viscosity as controlling factors in determining the velocity of crystallization of sucrose from real massecuites.

Methods

Massecuites were made up from various beet and cane final molasses. Most of the results herein reported are for a typical non-Steffens beet molasses (East Grand Forks factory of Americal Crystal Sugar Company) and a Cuban blackstrap (Pennsylvania Sugar Company). Solubilities were determined by Brown's (*1*) method; good correlation being obtained between drying and refractometric methods of determining dry substance when the latter method was previously standardized with the particular molasses under consideration. Grut's (*2*) tables of solubilities were found to apply to these beet syrups within reasonable variation, and the pattern suggested by Thieme (*10*) for cane syrups was also confirmed, although deviations from his average curve are marked.

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[1]Four previous papers in this series appear in Industrial and Engineering Chemistry, literature cited 11a, b, and c.

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[3]Italic numbers in parentheses refer to literature cited.

The rate of adjustment of non-saturated massecuites was followed refractometrically where possible and by a modified Nees' technique in others. These methods have been shown to yield comparable results (*7*, *11b*). To display significant differences most experiments were performed at an effective purity of 75 percent (*4*). Stock solutions of both the cane and beet molasses were made saturated at 30° C. at this nominal purity. In subsequent oversaturating, undersaturating, or addition of contaminants, etc., the impurity-to-water ratios of these base molasses were retained constant.

Saturation coefficients are expressed as oversaturations—the quotient of sucrose/water ratio in the actual massecuites to the same ratio in the same syrup when saturated at the same temperature. This is accepted practice in the cane industry and, in the light of previous experience for interpretive purposes, is considered superior to ordinary supersaturation coefficients (ratio of sucrose percentages), although frequently not as convenient.

The monomolecularity of the crystallization rate from these real massecuites was good for one-half to two-thirds of the total life. Thereafter the rate fell sharply. This behavior is similar, but the freedom from secondary reactions is not as extensive (to ¾ life) as has been observed with pure sucrose solutions (*11a*).

Diffusivities were measured by the Northrup-McBain (*11d*) porous disc technique. True purities of the resultant solutions were ascertained by the semi-micro method of Scales (*5*). Since only approximate viscosities were needed, rising bubble tubes were considered adequate.

Results and Discussion

1. Rates of Deposition of Different Crystalline Faces, and Comparison of Solution and Crystallization Rates.—Distorted and abnormal sucrose crystals are more frequently produced from impure syrups, thus suggesting an unequal and variable growth of the various faces. This is quite the opposite to a uniform rate of growth expected on the basis of a simple diffusion theory.

One might expect the dissolution of a crystal to be entirely controlled by a diffusion mechanism involving the dissipation of an adhering of film of saturated solution (*3b*). This is apparently the case with sucrose, as subsequent experiments reveal. But in comparing the rate of crystallization from pure sucrose solutions with that of dissolution at the same saturation potential, it is observed (*4*) that the former is a much slower process than the latter, again suggesting the inoperation of a diffusion mechanism as primary in the crystallization process. The same relative effect was observed with natural syrups in the present investigation; for example:

a. Refractometric technique—beet fillmass—75 purity, 30° C. Oversaturation and undersaturation 1.06 and 0.94 respectively

$$\frac{\text{Solution velocity (observed)}}{\text{Crystallization velocity (observed)}} = \frac{1.7}{1}$$

At 60 percent purity and 40° C. a ratio of 2.1 was observed for this same molasses.

b. Microscopic technique—cane massecuite—75 purity, 25° C. Oversaturation and undersaturation 1.12 and 0.88 respectively

$$\frac{\text{Solution velocity}}{\text{Crystallization velocity}} = \text{Between 1 and 2 with no stirring; above 3 at 1,000 r.p.m.}$$

2. Diffusivities.—The diffusivities and relative viscosities of the standard cane and beet molasses at 75 nominal purity and 0.96 undersaturation were determined at 30° and 63° C. Additional sucrose was added to some of these same syrups to give an oversaturation of 1.15 at the respective temperatures, and the rates of crystallization from these syrups were then determined. The results are given in table 1 together with pertinent calculations and information; the conclusion; as with pure syrups, is that crystallization is invariably the slower process and therefore rate controlling, or very largely so. The temperature coefficients are comparable to a few values available in the literature (*3a*, *6*) on the effect of various salts on the diffusion of sucrose.

Table 1.—Diffusivities, crystallization velocities, etc. of a cane and a beet syrup at comparable oversaturations and purities.

	Cane		Beet	
	30° C.	63° C.	30° C.	63° C.
Diffusivities—Integral, cm²/day	0.21	0.44	0.43	0.96
Diffusivities—pure sucrose (11d)	0.46	0.96	0.41	0.91
Relative viscosities	1	1.84 (55° C)	3.5	7.15 (55° C)
Relative crystallization velocity	1	4.1	0.78	2.56
Energy of activations, calculated from:				
Diffusivities	4.6		5.0 kCal/mol	
Viscosities	5.1		6.7	
Solution velocity	5.7 (bure cube)[9]		2.1 (low)	
Crystallization velocity	7.5		8.8	

The rate of solution of sucrose in an undersaturated beet molasses (S = 0.94) was ascertained at 30° and 40° C. and at 75 nominal purity in each case. The observed velocity at 40° C. was larger than that at 30° C. by a factor of 1.11. This 10° coefficient is considerably smaller than the 1.33 reported by Sandera and Mircev (*9*) for the leaching of pure cube sugar. However, both low values (corresponding to energies of activation of 2.1 and 5.7 kCal. respectively) emphasize the relative rapidity of the solution process and suggest the domination of a physical step. This situation emphasizes the need for close and uniform temperature conditions in boiling work (*12*); for any local overheating will reduce pan capacity much more significantly than an equivalent supersaturation condition can undo in the same time.

3. Effects of Stirring.—Generally speaking, a physically controlled process is more dependent on the rate of agitation within the system than is a chemically controlled system. That is, in the exponential curve—Velocity = $\propto$ $(N)^{\beta}$, where N is the rate of stirring, and $\propto$ and β are constants, the exponent is of small magniture if interfacial reactions control, while it approaches more nearly unity if a transport mechanism dominates. In the previous investigations (*11c*) of pure sucrose solutions, exponents of the order of 0.25 were typical, which was taken to indicate the controlling influence of an interboundary reaction. In the present instance the standard cane molasses was investigated, and the data presented in figure 1 are for two complete experiments in which effectively different stirring

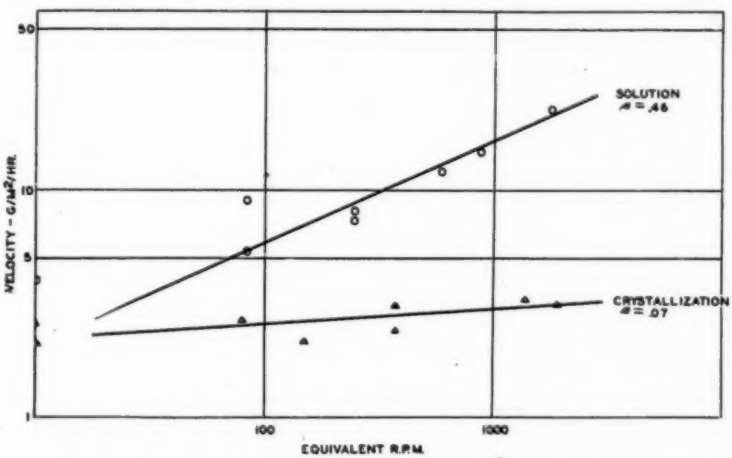

Figure 1.—Solution and crystallization velocities for standard cane massecuite. Both at same displacement from saturation.

speeds were realized by cementing the crystals to be grown at different distances along a common spindle.

The exponent (approximately 0.5) for solution, which process is expected to be a diffusion-controlled one, is not quite the perfect value of one (0.8 is more the typical limiting value (*8*), but the low value for crystallization, especially when compared to the higher solution value, is quite convincing in regard to the difference in the *modus operandi.*

For beet fillmasses, the limited data of Hungerford (*4*) gives exponents less than 0.12 when evaluated according to the above expression. This low value is again indicative of the absence of diffusion (and viscosity) control.

4. Effect of Additional Impurities.—A comparison of the effects of colloids on the viscosity and on the crystallization rate of sucrose from syrups is very revealing in the present connection. Approxmimately 5 percent by weight of caramel was added to the standard beet molasses at an oversaturation of 1.15. The viscosity of the syrup was diminished (0.8 of original value), while the crystallization rate dropped to 54 percent of its original value. In similar manner, an amount of gum acacia sufficient to increase the viscosity of this molasses six-fold effected no change in the crystallization rate (observed 3 percent increase). The melassigenic behavior of these and other constituents are thus directly contrary to what one would expect were a physical (diffusion or viscosity) process the primary controlling factor in sucrose crystallization.

The effects of these same two materials on the solution velocity of sucrose was ascertained to concur with the expectation that diffusion is the controlling factor in this case; namely, it was found that caramel had little influence on the rate of solution whereas acacia impeded the process tremendously.

Summary and Conclusion

The rate of growth of sucrose from real massecuites, as well as from pure solution (*11*), is determined primarily by some interfacial (homogeneous, chemical) reaction rather than an interboundary (heterogeneous, physical) reaction.

Acknowledgment

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individuals who supplied the samples of cane and beet products utilized in this and related investigations.

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Sieve Tests and Fineness Modulus of Granulated Sugar

A. R. Nees[1]

The users of sugar, especially the commercial users, are making increased demands for sugars of various types based on grain size. Some candy makers want coarse sugar because it handles better in their kettles, bakers want fine sugar because it creams more easily in cake batter, and many housewives want an intermediate size which is neither coarse nor fine. If the sugar manufacturers are to supply sugar to meet these demands, it is necessary to have a standardized method for determining the grain size, and to set up specifications for the various types. It is also necessary to decide on the types which most nearly meet various market demands and to produce these types as standard products. It is highly desirable, though perhaps a bit idealistic, that the standard types be produced by all manufacturers so that a uniform product is available everywhere.

It is the purpose of this discussion to make tentative suggestions concerning the solution of these problems.

Sieve Tests

The determination of particle size by sieve tests is familiar to everyone. To the writer's knowledge, very little effort has been made in the sugar industry to standardize the type of sieves to be used or the methods of using them. The first step, therefore, is to decide on the type and sizes of sieves. A number of sieve series are available, but it is desirable that one be selected which is generally accepted as standard. The American Society for Testing Materials has adopted the National Bureau of Standards sieve series and the practically identical Tyler Standard Screen Series of sieves.

The Tyler scale has as its base an opening of .0029 inch which is the opening in the 200-mesh sieve using 0.0021-inch wire; the opening increases in the ratio of the square root of 2, or 1.414. The area of the openings, therefore, increases in the ratio of 2. For closer sizing intermediate sieves are available. In the complete series the sieve openings increase in the ratio of the fourth root of 2, or 1.189, and the area increases in the ratio of 1.414.

The U. S. sieve series, designed by the Bureau of Standards, uses a 1-mm. opening as the base, the opening varying in the same ratio as the Tyler series. The result is that the two series are practically identical. It is suggested that either of these series may be adopted as

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standard. The writer's laboratory uses the Tyler series. In both the U. S. and Tyler series the sieves are designated by number and not, as is usually the case, by the number of openings per linear inch.

The set of sieves listed in table 1 has been selected as suitable for use in testing sugars:

Table 1.

Sieve No.	Openings per inch	Diameter of openings	
		Inches	mm.
12	10	.065	1.651
16	14	.046	1.168
20	20	.0328	.833
30	28	.0232	.589
40	35	.0164	.417
50	48	.0116	.295
60	60	.0097	.246
70	65	.0082	.208
80	80	.0069	.175
100	100	.0058	.147
140	150	.0041	.104
200	200	.0029	.074

For the average run of granulated sugar, sieves Nos. 30 to 100 are all that are required. If very close sizing is desired, sieves Nos. 35 and 45 may be included in the series since about 70 percent fall in the range of −30 +50. However, for routine tests such sizing is of doubtful value. The intermediate series, 60 and 80, have little value in tests on average sugars as produced but are included because of their use in establishing suggested commercial types to be discussed later.

The method of making sieve tests has been standardized and the following procedure is recommended:

A Tyler Ro-Tap Sieve Shaker has been adopted as the screening apparatus. Eight-inch-diameter, half-height sieves are used. One hundred grams of sugar are weighed into the coarsest of the nest of sieves, which is placed in the Ro-Tap and shaken for 10 minutes. The various fractions are weighed and the results reported in the usual way. When testing the product from factory screens where the size range lies within narrow limits, a 50-gram sample should be used to avoid overloading the sieves. It is particularly important to avoid overloading the finer sieves, No. 60 and under. This method has been found to give reproducible results when the same 100-gram sample is recombined and retested, as is indicated in table 2.

The most serious difficulty in obtaining accurate sieve tests is in getting a truly representative sample. This is especially difficult when the range of grain size is large and the size distribution uneven,

Table 2.

U. S. sieve No.	Repeated tests on the same 100-gram sample		
	(1)	(2)	(3)
+30	1.0	0.9	0.8
−30 +40	21.1	21.2	21.1
−40 +50	48.6	48.4	48.5
−50 +60	13.0	13.2	13.3
−60 +70	8.3	8.3	8.3
−70 +80	4.3	4.3	4.3
−80 +100	2.4	2.3	2.5
−100	1.2	1.2	1.2

as is the case for practically all unscreened factory sugars. No amount of mixing or, so far as the writer knows, no method of mixing will prevent some segregation so that successive portions taken from the same sample may show rather wide variations. When the size range is narrow, as in the case of factory-screened sugars, this difficulty materially decreases and satisfactorily concordant results can be obtained.

Too little work has been done to establish the range of variations due to sampling. Some indications as to the character of the problem are illustrated by some tests made recently in the writer's laboratory. The sugar from the sieve tests of 57 samples was recombined into a single composite and the weighted average sieve test calculated. The entire composite was placed in a closed container and thoroughly mixed. A series of tests was made on the mixture. After each two or three tests the whole sample was remixed. A total of eight tests and three mixings were made. After this the samples were again recombined, remixed, and passed through a "Jones" ore sampler until the weight had been reduced to approximately 100 grams. On the last pass through the sampler there were, of course, two such portions (a) and (b). Sieve tests were made on both. Data for the above tests are shown in table 3.

It is noted that samples taken from the mixed composite invariably indicated the sugar to be finer than it really was, while the samples obtained from the "Jones" sampler checked the calculated composition very closely. When an accurate test on a given sample of sugar is desired, this method is recommended.

The results of a sieve test reported in the usual manner are difficult to interpret. It is desirable, therefore, to express the average fineness or average grain size by a single number which may be called the "fineness modulus". There are numerous methods of calculating the average particle size; each one is mathematically sound and each one gives a different result. The point is to choose the method of calculation which suits the purpose for which the figures are to be

Table 3.

U.S. sieve No.	Weighted average of 57 samples	Eight tests on composite of 57 samples			Final, split from "Jones" sampler	
		Minimum	Weighted Average	Maximum	(a)	(b)
+30	2.5	2.1	2.1	2.1	2.4	2.8
-30 +40	28.3	25.7	26.3	26.9	28.3	28.6
-40 +50	44.1	42.2	43.4	44.4	44.2	42.8
-50 +60	11.0	11.6	11.7	11.4	11.2	10.9
-60 +70	6.8	7.8	7.8	7.5	6.9	6.9
-70 +80	3.4	4.5	4.0	3.9	3.5	3.7
-80 +100	2.6	3.7	3.0	2.6	2.4	2.6
-100	1.3	2.4	1.7	1.3	1.1	1.5
Avg. diam. of crystal, mm.	0.373	0.356	0.362	0.365	0.371	0.371
Fineness modulus	51.6	45.1	47.4	48.6	51.1	51.1

used. For the present purpose it is desirable to use a modulus which will express the relative grain size as it appears to the eye and one which is simple to calculate. After considerable exploratory work, such a modulus has been devised; the derivation is explained in the following paragraphs.

In the first place it is necessary to determine the average grain size in any given sieve fraction, for example, the average grain size which passes No. 40 sieve and is retained on No. 50. A number of calculations were tried, but the one which appears to meet the conditions best is the simple geometric mean of the adjacent sieve openings.

$$\text{Mean Diam.} = \sqrt{D \times d}$$ where D and d are diameters of the sieve openings.

The reason for adopting this value is shown in figure 1. The sieve openings in mm. are plotted against the sieve number on a semi-log scale. The plot is, of course, a straight line. It will be noted that the geometric mean of any two sieves falls on the line at exactly the midpoint between the sieves. This method of calculating the mean therefore conforms to the characteristics of the sieve series. The mean values for the entire series are given in figure 1.

In order to simplify future calculations, the values of the mean diameters are rounded off as indicated under the heading "Modulus Factor" in figure 1.

Having established the mean grain size for each sieve fraction, it still remains to calculate a "fineness modulus" for any given sieve test. The simplest and for the present purposes the most practical

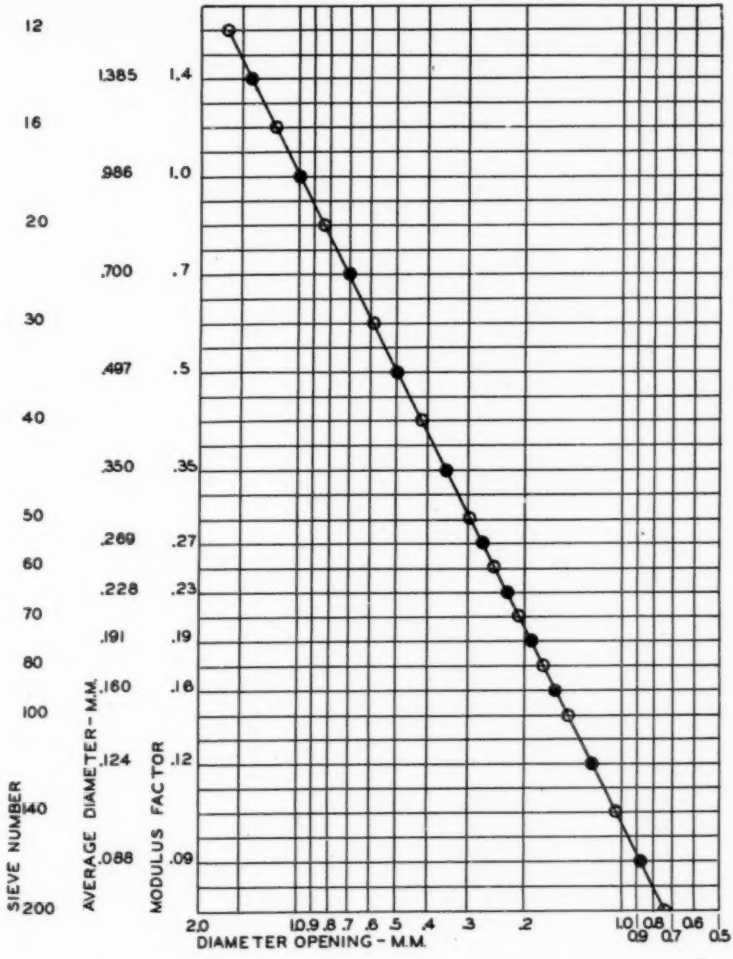

Figure 1.—

method is to take the arithmatical average of the mean grain size of all the sieve fractions. This is done by taking the product of the percentage and the modulus factor for each fraction and dividing the sum of the products by 100. This method is illustrated by the following example:

Sieve test		Modulus factor	(2) x (3)
Sieve No.	Percentage		
(1)	(2)	(3)	(4)
-20 +30	1.2	0.7	.84
-30 +40	34.2	0.5	17.10
-40 +50	43.2	0.35	15.12
-50 +60	9.0	0.27	2.43
-60 +70	4.8	0.23	1.10
-70 +80	3.8	0.19	.72
-80 +100	2.4	0.16	.38
-100	1.4	0.12	.17
			37.86

$$\text{Avg. diam. of grain} = \frac{37.86}{100} = 0.3786 \text{ mm.}$$

It may appear inconsistent to use the geometric mean for determining the average grain size between successive sieves and the arithmetical mean for the overall average. This is done for the sake of simplicity. The geometric mean appears to be more accurate, but the difference is very small and its use involves constant reference to a table of logarithms. Briefly, the method is to use the log of the mean sieve opening as the modulus factor, which is applied in the same manner as illustrated above. The overall mean grain size is the anti-log of the sum of the products.

At this point the question arises as to the best method of expressing the results in terms of a "fineness modulus" so that the modulus will be consistent with the appearance to the eye. The first thought is to use the mean grain size or a multiple of it as the modulus. This puts the modulus on the basis of a linear function, that is, the diameter of the crystal. The chief objection is that there is a very small spread in the modulus of many sugars so that judgment of what constitutes a significant difference becomes difficult. This objection can be overcome by stating the modulus in terms of the volume of the average crystal. This is done by taking the cube of the average diameter as determined above. In order to avoid unwieldy fractions the cube of the average diameter is multiplied by 1,000 and only one figure to the right of the decimal point is carried in the final result. The method of calculation is expressed by this equation:

$$M = \frac{(\Sigma FW)^3}{(100)} 1000$$

M = Fineness modulus
F = Modulus factor
W = Percentage in each fraction

Referring to above example:

$$M = \frac{(37.86)^3}{(100)} 1000 = 54.3$$

Table 4 will illustrate the foregoing points. The figures were obtained from actual sieve tests on run-of-factory sugars.

Table 4.

Sample No.	Avg. diam. mm.	Fineness modulus	Sample No.	Avg. diam. mm.	Fineness modulus
1	.321	33.1	13	.364	48.0
2	.326	35.5	14	.366	48.8
3	.332	36.6	15	.370	50.5
4	.333	36.8	16	.374	52.0
5	.341	39.6	17	.379	54.2
6	.342	40.0	18	.384	56.5
7	.345	41.1	19	.389	59.0
8	.354	44.5	20	.392	59.8
9	.356	45.1	21	.396	61.6
10	.358	45.9	22	.399	63.7
11	.359	46.2	23	.415	71.5
12	.363	47.9	24	.428	78.1

An objection to the use of this modulus is that it becomes quite large when applied to coarse sugars. This is illustrated by the examples given in table 5.

Table 5

Sieve No.	Percentage (W)	Modulus factor (F)	Modulus
−12 +16	100.0	1.4	2,744.0
−16 +20	100.0	1.0	1,000.0
−20 +30	100.0	0.7	343.0
−30 +40	100.0	0.5	125.0

It should be noted that astronomical figures occur only when dealing with special sugars which are a very minor part of the total production. It does not seem logical to discard an otherwise satisfactory method on this account. The writer's laboratory has, therefore, tentatively adopted this method of reporting "fineness modulus" pending further developments.

Standard Types of Commercial Sugars

In the beginning of this paper reference was made to selecting and setting up specifications for commercial types of sugar based on grain size. With full realization of the controversial aspects which are involved, the writer suggests the following five types as meeting a large majority of the commercial and household demand.

The fraction −12 +20 designated as "Sanding"
−20 +40 designated as "Standard. Granulated"
−40 +60 designated as "Table"
−60 +80 designated as "Bakers"
−80 +200 designated as "Dessert"

The fineness modulus, assuming an ideal distribution of size in each fraction, are:

"Sanding"	1,728.0
"Standard"	216.0
"Table"	29.8
"Bakers"	9.3
"Dessert"	2.7

The foregoing description of the types is based on the assumption that 100 percent falls within the sieve limits designated and that there is a uniform size distribution in each sieve fraction. These conditions, of course, are impossible of attainment in commercial practice. Therefore it is necessary to complete the specifications by setting up limits of tolerance. The lack of sufficient data on the performance of commercial sieves makes this difficult to do at the present time. In order to get preliminary data on allowable variations, synthetic mixtures of each of the types were made up, varying the percentage oversize and undersize, as well as the size distribution. The example given in table 6 will serve to illustrate the results.

Table 6

	"Table Sugar" Rated sieve size −40 +60				
Actual composition	Example (1)	Example (2)	Example (3)	Example (4)	Example (5)
−30 +40	5	5	5	5	0
−40 +50	60	30	50	30	50
−50 +60	30	60	30	50	50
−60	5	5	15	15	0
Avg. diam. mm.	.330	.306	.315	.299	.310
Modulus	35.9	28.7	31.3	26.7	29.8

Observation of slides projected on a screen gave visual evidence that No. 1 was coarse and No. 4 finer than No. 5. Very little difference could be distinguished between Nos. 2, 3, and 5. On the basis of these observations the following tentative tolerances were set up, subject to change as further data are accumulated:

	Modulus	
	Minimum	Maximum
Sanding	1,400	2,000
Standard	200	225
Table	27	33
Bakers	8.5	10
Dessert	2.3	3

The limits, of course, become less for the finer types. It is possible to have sugars fall within the given modulus range which would not conform to the classification indicated, because of wide size variation. Therefore in applying these specifications it is understood that at least 80 percent falls within the rated sieve range.

It was stated in the beginning that the purpose of this discussion is to propose a standardized method for determining the average grain size of granulated sugars, and to suggest specifications for standard types which will meet the growing demand of the commercial and household users. It is fully realized that much yet remains to be done, but it is hoped that through cooperation of the industry as a whole a mutually satisfactory solution of the problems will be reached.

Summary

The Tyler Standard Screen Series or its equivalent is recommended for making sieve tests on granulated sugar. A standard method of making the tests is described. A numerical expression for the average crystal size is derived and termed the "fineness modulus". Five commercial types, based on fineness, which most nearly meet various consumer demands, are suggested and their specifications set up.

Chemical Study of Beet Pectin

ELIZABETH ROBOZ and ANDREW VAN HOOK[1]

Considerable attention has been given recently to the by-products of the sugar beet, aiming at its better utilization. It is recognized that the by-products are good sources of various chemical compounds with industrial possibilities. Our present investigations are concerned with one of these by-products—the pectin extractable from the pulp.

The chief use for pectin, currently, is in the food industry as a jellying agent. Many medical applications are possible (*6*)[2]; to mention a few—in treating stomach and intestinal disorder with an apple diet the effective constituent is the pectin (*9*) contained therein; pectin has healing properties and plays a role in the detoxication mechanism (*7*) by means of its chief constituent, galacturonic acid; pectin works as an active coagulent (*3*) (hemostatic agent).

The main sources of industrial pectin in the United States are citrus fruit waste and apple pomace. The physical properties of citrus and apple pectins, such as viscosity, jelling qualities, etc., differ greatly from the pectin of the sugar beet. The possibility of utilizing sugar beet pectin as a constituent of jellies has been generally dismissed on account of its poor jelling qualities. However, according to recent private communications, beet pectin has been used on a large scale for jelly-making in Germany during the past war years—probably one of their many "ersatz" materials. Even if pectin from the beet is inferior for making jellies and jams, it could be used for other purposes such as pharmaceutical preparations, thickening agents, source of galacturonic and tartaric acids, etc.

Pectin is present in many plants and as a hydrophylic colloid plays a role in the translocation of water. The quantity of the pectin diminishes through the ripening process, and enzymatic hydrolysis of the pectin results in softening of the fruit. However, this transformation is not observed in the sugar beet. The seasonal variations are not significant and the mature beet at harvest time has as hard a texture as the unripe.

The pectin, as present in the plant, is called protopectin and is insoluble in cold water but can be extracted with warm water, acid, basic or salt solutions. The rate of extraction is determined princi-

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[2]Italic numbers in parentheses refer to literature cited.

pally by pH; the greater the deviation from the neutral point, the faster the extraction.

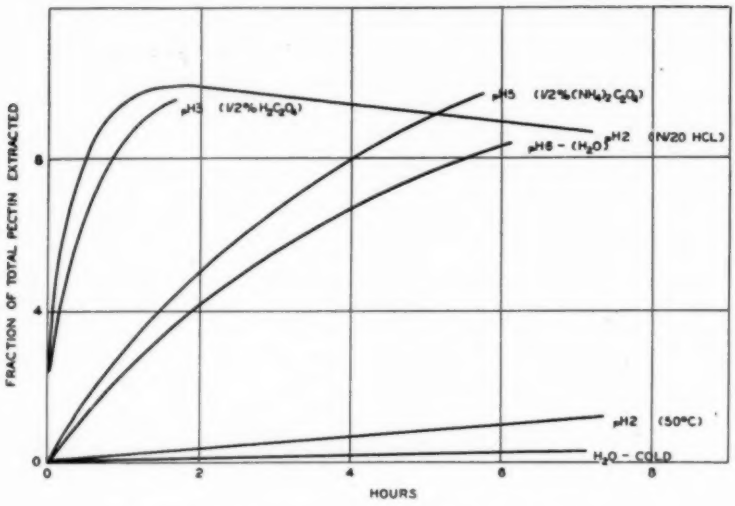
The constitution of the pectin, which is a complex polysaccharide, is not yet exactly known. According to Ehrlich (*4*), who did the most extensive research on beet pectin, it is an ester-acid with two of its carboxyls bound with two molecules of methyl alcohol in an ester linkage in cyclic arrangement of four glacturonic acids, called tetragalacturonic acid; arabinose and galactose are part of the pectin molecule. Other investigators came to the conclusion that the arabinose and galactose are loosely attached to the galacturonic acid unit (*5, 13*).

An extreme conception of the role of arabinose and galactose was expressed by Schneider (*12*), who reported that the presence of arabinose in the pectin molecule depends only on its solubility—if treated with 70 percent alcohol several times, more arabinose is removed each time. After five to six reprecipitations, an equilibrium is established between arabinose and pectin; then, by changing the ratio of the percentage of alcohol, the arabinose is removed completely and a purified pectin free of arabinose and galactose (galacturonic acid, 96 percent; CH_3OH, 11 percent; arabinose, 0 percent; galactose, 0 percent) is obtained. According to Schneider, this highly purified pectin has good jelling properties. Schneider disagrees with Ehrlich's conception that pectin is built on a frame of four galacturonic acids and reputes his cryoscopic molecular weight determinations as being too low. Through molecular weight determinations carried out on the nitroproduct of pectin, Schneider obtained values between 20,000 and 100,000. The treatment with nitric acid might result in lower molecular weight due to oxydative degradation, but never in a higher one. Consequently, the molecular weight of the pectin before nitration should be higher. According to him pectin consists of eight galacturonic acids.

Bauer and Link (*1*) have been given 10 galacturonic acids as a unit in pectin, proved by complete methylation and hydrolosis of the methyl-ester and determination of the end group.

X-ray studies (*8, 2, 11*) are also in contrast to the Ehrlich's work because they indicate a long chain molecule somewhat similar to cellulose. In Ehrlich's presentation every pectin is a well-defined compound, and the ratio of galactose and arabinose to the galacturonic acid must be in agreement with his formulae; if not, the pectin is degraded because of fermentation or hydrolysis. According to our present knowledge, the composition of pectin varies depending on the origin and method preparation.

We are attempting to prepare highly purified pectin from beet pulp in order to investigate structural composition and relationship.



Experimental Parts and Description of Results

In this paper we shall outline our investigations to date on the preparation and properties of beet pectin.

The effects of time, temperature, pH, and solvents on the rate and amount of extractables of dried pulp were studied. The results are presented in figure 1 and table 1. Crude pectin is the portion of total extractable precipitated at pH 2-3 in a 66 percent volume of alcohol water medium. By the alcohol water soluble fraction is meant that portion remaining in solution after precipitating the crude pectin.

Table 1.—Extraction of pectin.

Solvent used	pH	Temp. C°	Time in hours	Ratio pulp/ solvent	Soluble in alcohol -water mixture	Insoluble: crude pectin
Hydrochloric acid	5	90°	5	1:20	14.0%	34.0%
Ammonoxalate	5	90°	5	1:20	6.4%	34.0%
Hydrochloric acid	2	90°	2	1:10	14.4%	43.0%
Ferrosulfate	4	80°	2	1:10	6.0%	22.0%
Hydrochloric acid	2	80°	4	1:20	34.0%	32.0%
Water	6.5	90°	6	1:20	13.5%	27.0%

Table 2.—Composition of pulp.

Pulp	Dry substance (percentage)	Ash (percentage)	Nitrogen (percentage)	CaO (percentage)	CaO in ash (percentage)	Galacturonic acid (percentage)	Arabinose (percentage)
Pressed	19.8	2.99	1.61	0.92	31.1	27.25	25.60
Dried	91.7	4.0	1.76	1.32	35.8	32.70	17.50

We can see from the figures that the acidity and temperature are the dominating factors in effecting a rapid extraction of the pectin from its pulp. If the extraction is continued beyond the optimum, or if more concentrated acids are used (2½ percent), the yield of crude pectin is decreased, probably the result of acid degradation. The smaller amount of nonpectin extractables in the cases of water, ammonium oxalate, etc., are ascribed chiefly to the lesser solubility of the various constituents of the parent pulp.

Our standard procedure for obtaining representative amounts of pectin consists in extracting a 1/20 pulp to liquid ratio with n/20, normal HCL, at 90° C., for 1½ hours with constant stirring. While still warm the pulp is pressed out, cooled to approximately 32° to 34° C., the pH raised to 4, and clarifying enzyme added for 50 minutes. These enzymes destroy starches and proteins. After 50 minutes the solution is warmed to counteract the further effect of the enzyme on the pectin.

For these extractions we used pressed pulp and dried pulp. The chemical composition of the pulp and the pectin was determined in order to ascertain the effect of drying on the composition of the pectin. The analytical data are presented in tables 2 and 3.

According to these data there is no significant difference between the two pulps—pressed and dried—so that there is no apparent adverse effect of drying; however, the preparation of pectin from the pressed pulp is an easier operation, the color of the extract is lighter, and the filtration is quicker.

Table 3.—Pectin from pressed and dried pulp.

Pulp	Ash (%)	Arabinose (%)	Galacturonic acid (%)	Methoxyl content (%)
Pressed	2.89	9.95	64.5	8.85
Dried	5.97	13.08	67.8	8.37

Table 4.—Recovery of pectin.

Treatment: Alcohol used for precipitation by volume (percentage)	Pectin recovered at pH 2-3 (percentage)	Additional pectin recovered at pH 8 (percentage)	Total recovered pectin (percentage)
50	57	24	81
65	75	10	85
70	79	7	86
80	86	6	92
70 (acetone)	87	13	100

In table 4 we present data of the recovery of pectin. The recovery of pectin is carried out by means of precipitating with ethyl alcohol. In our experiment we used various concentrations of alcohol at different pHs. The best recovery was accomplished with 80 percent alcohol. The higher the alcohol concentration the more pectin is precipitated, but this pectin is more impure because other alcohol insoluble substances are present.

The influence of enzyme to assist in the preparation of (table 5), pectin prepared from pressed pulp and also from dried pulp was studied. The higher galacturonic acid and methoxyl content of the enzyme-treated products indicates that enzymes are a good means of improving the extract before precipitation of pectin.

The chemical constituents of the acid-treated pectins are compared with the alkaline-treated ones in table 6. As seen from the figures, the methoxyl content of the alkaline-treated pectin is much lower

Table 5.—Influence of enzyme treatment.

Condition of extraction	Ash (%)	Arabinose (%)	Galacturonic acid (%)	Methoxyl content (%)
Pectin from pressed pulp:				
Clarified with enzyme filtered	2.52	6.80	65.0	9.30
Not clarified, not filtered	5.79	10.00	60.3	8.37
Not clarified, filtered	2.26	7.8	61.5	8.68
Pectin from dried pulp:				
Clarified, filtered	3.06	8.60	62.2	8.18
Clarified, not filtered	4.33	8.40	60.6	8.22
Unclarified, filtered	3.70	9.60	59.3	7.92

Table 6.—Comparison of the chemical constituents of the acid- and alkaline-treated pectins.

Treatment	pH	Ash (%)	Galacturonic acid (%)	Arabinose (%)	Methoxyl content (%)
HCL	2.0	2.89	64.50	9.95	7.85
NaOH	7.6	5.72	61.50	7.44	5.70
NH_3	8.0	3.58	72.30	6.26	6.67
NH_3	9.0	3.80	75.30		5.89
NH_3	11.0	3.03	67.45		2.10

than those treated with acid. When the pectin is treated with alkaline, partial deesterification takes place, yielding low methoxyl pectin (*10*). If the pectin solution stands from 5 to 6 hours at pH 9, the methoxyl content drops from 7.85 to 5.70. At pH 11, the desterification goes as far as 2.10 percent of methoxyl. The demethoxylation is not just a singular change in the molecule as Hills (*13*) and co-workers point out, but several reactions might take place which change the behavior of the resultant low methoxyl pectin.

Purification of Pectin, Table 7.—Twenty-five grams of crude pectin prepared from dried pulp was dissolved in 500 cc. of distilled water using a Waring blender for dispersing the pectin. It was clarified with active carbon and filtered through celite filter aid. Without concentrating it was precipitated with alcohol in the ratio of 1:2.5; the precipitate was washed twice with 80 percent alcohol making it acid with HCl to pH 3, and twice with 95 percent alcohol. Centrifugal separation was employed in place of filtration. A small

Table 7.—Purification of pectin; influence of reprecipitation on the composition.

Number of precipitations with alcohol	Ratio of water to alcohol	Ash (%)	Galacturonic acid (%)	Arabinose (%)	Methoxyl content (%)
0	1:2.5	5.97	67.8	12.37	7.75
1	1:2.5	5.06	67.9	9.02	8.52
2	1:2.5	4.25	68.3	6.64	8.68
3	1:2.5	3.51	70.3	6.50	9.27
4	1:2.5	2.85	69.1	8.70	9.00
5	1:1	1.41	71.9	8.30	9.98
Dialysed and precipitated	1:1	0.96	76.0	7.30	10.70

quantity at each operation was washed with ether and saved for analysis. The same procedure was repeated up to the fourth precipitation. The fourth precipitation did not increase the methoxyl content and galacturonic acid any further. Upon changing the ratio of water and alcohol to 1:1, more ballast material was removed and the methoxyl and galacturonic acid content increased. It was then dialyzed against distilled water. We succeeded in reducing the ash during the purification process from 5.97 to 0.96. We shall attempt to de-ash the beet pectin by the use of ion-exchange agents (as it was done with citrus pectin) in order to further reduce the inorganic salt content.

As we see from the figures, the methoxyl went up from 7.75 to 10.70 and the galacturonic acid from 67.8 to 76.0.

Physical Properties of Beet Pectin.—The viscosity of aqueous solutions is one of the most significant properties specifying the quality of various pectins. In this respect all of the beet pectins prepared under acid conditions exhibited only minor variations, within relative values of 2.6 to 3.0 for one-half percent solutions at 25° C. Even repeated precipitation, coagulation at different alcohol strengths, etc., did not change the relative viscosity appreciably. Alkaline precipitated materials exhibited tremendous decreases in viscosity behavior as well as methoxyl contents. This is exhibited in table 8, which also includes typical values of fractions precipitated under different conditions. For comparative purposes the relative viscosities of typical citrus and apple pectins were ascertained to be 4.0 and 5.0 respectively.

Table 8.—Relative viscosities of pectin precipitation at different concentrations of alcohol.

Treatment			
pH	Precipitation with alcohol (%)	Relative viscosity 0.5-percent solution (250° C.)	Methoxyl content (%
2	50	2.38	8.50
2	60	2.66	8.30
2	70	2.35	— —
2	80	2.39	9.50
(repreci. 6 times)			
2	65	2.80	10.70
8	65	1.80	5.70
9	65	1.13	2.50
11-12	65	1.10	2.10

The relatively low viscosity values, as well as direct tests, confirm the general impression that ordinary sugar beet pectin is a non-jellying type. In fact the best consistency obtained in our experiments was about equivalent to ordinary vaseline salve. This jell did not "cut" well.

It was observed qualitively that several of the pectins produced exhibited a viscosity which seemed to increase tremendously upon acidifying. Since this is a characteristic of pectins capable of forming low sugar jells, we investigated these materials further although they did not meet the differentiating value of 0.5 in the degree of methoxylation (*13*). In no case was anything better than a very thick viscous liquor obtained. With a demethoxylated product (2.1 percent OMe, 0.16 degree of methoxylation) the result was the same.

Discussion

The sugar beet pectins prepared for this study are apparently of the same general chemical nature as those derived from fruit sources. This is obvious from examination of the galacturonic acid, arabinose, methoxyl content, etc. They meet and even exceed the minimum requirements set up by the National Formulary for Commercial pectins and can be purified to an extent suggested for pure pectins.

The National Formulary does not specify any gelling qualities for pectins since it is felt that this behavior is still a highly arbitrary matter. In this respect the beet pectins, as prepared at the present time, are different from those of other sources. The difference is apparently not one of chemical nature, since the beet pectins satisfy these requirements of reactivity. As first suggested by Schneider, the defect is to be influenced by a relatively lower molecular weight of the pectins derived from the beet. His representative values are:

Citrus pectin	150,000 to 220,000
Apple pectin	90,000 to 280,000
Beet pectin	20,000 to 25,000

The same relative order was confirmed in this work by means of viscosity measurements as presented in table 9. The absolute order of these values is also designated by the value of 43,000 to

Table 9.—Viscosity of pectin of different sources.

0.5 percent Solution	Relative viscosity at natural pH
Citrus 150 grade	4.0
Apple 237 grade	5.0
Crude beet pectin	2.5

46,000 ascertained through the courtesy of Dr. H. Owens of the Western Regional Laboratory, for the standard beet pectins prepared by us.

The possibility remains that this low molecular weight may be the consequence of the comparatively drastic treatment encountered in previous factory operations. However, we have made preliminary experiments indicating that beets, extracted under conditions found to be most favorable for the production of maximum quality of citrus pectins, yield a product of the same general nature and gelling quality as the product from pulp.

The question of the effect of pretreatment and extraction conditions in this property, as well as the possibility of increasing the molecular size of the derived product, is to be investigated further.

Summary

The pectin in beet pulp was investigated by chemical and physical means.

The rate, time, temperature, pH, and concentration, as related to the extraction, were studied.

The pressed and dried pulp and the pectin prepared from both were analyzed and compared; no adverse effects of drying could be detected on this basis.

The effect of enzyme for clarification on pectin from pressed and dried pulp was studied in both cases; the beneficial effect of enzyme treatment was prevalent.

The alkaline treatment of pectin showed a decrease in methoxyl content.

Purification of pectin was carried out by repeated precipitation and subsequent dialysis. The increase in galacturonic acid and methoxyl content and decrease of ash was significant.

The physical properties—molecular weight, viscosity, and jelling properties were examined and discussed in connection with standard citrus pectin.

Acknowledgment

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Ion Exchange Applied to Sugar Juice Purification

E. A. Haagensen[1]

The process for recovering sugar from sugar beets has existed in its present form substantially unchanged since its inception over 100 years ago. There have been many improvements in technique and equipment but the essential methods have remained relatively the same. Now a new process of juice purification has been developed that promises to remove most of the non-sugars and permit recoveries of 95 to 96 percent without resort to the Steffenizing of the molasses.

The process makes use of the new synthetic resinous ion exchangers developed during the past 10 years. It is only with the advent of these new high capacity, durable, synthetic materials that the use of ionic exchange has become practical and economical for sugar and many allied purification problems. This paper will discuss only the purification of the sugar juice, although the recovery of valuable by-products is possible and practical as indicated in some of our research.

The Dorr Company has been actively working on the application of ion exchangers to sugar juices and has cooperated with the Amalgamated Sugar Company in extensive experiments on a laboratory and pilot plant scale. As the principles and theories of ionic exchange reactions have been presented by others, they will not be discussed here.

Table 1 shows the results of the final 10-day run at the Burley Pilot plant in 1942. This table shows the results achieved on a continuous 10-day run. This pilot plant treated an average of 20,000 gallons of juice per day, which was equivalent to that from 560 tons of beets containing 16.3 percent sugar with 0.30 per cent beet-end losses.

This table is based on results achieved when treating second carbonation juice. From the quantities it is apparent that to remove 1 pound of non-sugars, there is required approximately 1 pound of 66° Be' sulphuric acid and 0.6 pound of soda ash (Na_2CO_3). This then is the direct chemical cost of treating a juice. From an average figure on elimination of non-sugars of 72.6 percent it is seen that per pound of non-sugars originally present, it will require about 1.4 pounds of 66° Be' sulphuric acid and 0.83 pound of soda ash to give this 72.6 removal. These results were with Idaho beets and will change slightly depending on the organic ash ratio of the non-sugars present in the juice. In general the organics have higher equivalent weights than ash constitutents, and so per pound of chemical regenerants there will be more pounds of non-sugar organics removed than inorganics. Here it may be well to state that the general theory is that the ionic ex-

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Table 1.

	Feed to station						Finished juice					
	No. cycles on station	No. samples to laboratory	Brix	Apparent purity	Percentage invert on D. S.	Percentage conductivity ash on D. S.	Brix	Apparent purity	Percentage invert on D. S.	Conductivity ash percentage on D. S.	Percentage ash elimination	Percentage elimination based apparent purity and invert
1.	7	2	12.9	92.4	0.0	3.09	11.1	98.3	0.50	0.20	94.0	85
2.	18	9	12.9	92.1	0.0	2.89	11.1	98.0	0.50	0.20	94.0	85
3.	20	10	11.9	91.3	0.0	3.41	10.0	97.3	0.32	0.30	91.8	74
4.	22	11	12.1	91.3	0.01	3.32	10.3	97.3	0.10	0.28	92.0	72
5.	21	11	11.8	91.5	0.06	3.16	10.2	97.0	0.21	0.20	94.2	69
6.	23	11	11.2	91.3	0.16	3.69	9.6	96.2	0.50	0.30	92.4	63
7.	22	11	12.0	91.3	0.03	3.32	10.2	96.2	0.47	0.28	92.0	64
8.	25	12	12.0	90.9	0.21	2.96	10.3	97.1	0.31	0.30	90.5	73
9.	23	12	12.9	91.2	0.00	2.89	10.9	97.1	0.30	0.26	91.5	72
10.	24	11	12.5	91.6	1.00	3.32	10.4	97.3	0.54	0.28	92.1	76
11.	7	5	12.4	91.5								
TOTALS	212	105										
AVERAGE			12.2	91.5	0.05		10.45	97.14	0.34	0.257	92.5	72.6

Average gallons juice per cycle out—1,015. gallons
Average tons beets per cycle 2.65. tons

12,000 pounds H_2SO_4 used
7,350 pounds Na_2CO_3
12,500 pounds impurities removed — calculated

change resins remove only those substances that ionize, although there is evidence that colloid and some other substances are removed also. This colloid removal, however, may be due to electrical charges borne by the colloids being neutralized by the exchanges or to the fact that pH changes occur during treatment.

There is an increase in the invert sugar content and as a corollary we may state a decrease in sucrose content of the treated sirup. This increase in invert sugar averaged 0.29 percent on dry substance for the final run. Inspection of the daily results will show results varying from 0.09 percent to 0.54 percent. Checks over isolated portions of the complete de-ionization station show that most of this inversion was due to bacterial action at the filter press and cooler. When these sections were kept clean, the inversion was minimized. The inversion due to the exchanger treatment was low and can be expected to be below 0.10 percent on sugar.

This subject of inversion is interesting. The pH of the juice (12-14 Brix) after passing through the cation exchange is around 2.0 and it is in the acidic state less than 3½ minutes when operating on a 6-foot deep exchanger bed. Now a pH of 2.0 is equivalent to a hydrochloric acid solution of 0.01 normal which will cause inversion of the order of 0.02 percent or less in 3½ minutes. The remaining inversion is due to the catalytic action of the cation exchange resin itself because the cation exchange resin may be looked upon as a solid acid with only its hydrogen ion in solution. Later results on inversion show that it may be kept below 0.1 percent on sugar with good temperature control and rapid treatment.

The dilution due to sweetening-off was calculated at 10 percent for the runs tabulated. This is higher than would be achieved in practice with the exchanger then used and would not normally be this much with that particular exchanger. However, because of operating conditions at the time it was not possible to control sweetening-off as well as desired. Newer exchangers of higher capacity will mean less dilution. Since dilution is due to sweetening-up and sweetening-off, it is a function solely of the volume of resins. Therefore, with a resin of higher capacity, more sugar sirups of the same non-sugar content can be passed through before they are exhausted and consequently less in the overall picture. The amount of dilution will be in inverse ratio to the capacity of the resin in question. Consequently the higher capacity resins will show better savings.

This dilution, however, does mean extra work on the evaporators. During the pilot plant run in 1942 dilution amounted to about 35 gallons of water per ton of beets. With newer high capacity exchangers, this will decrease to approximately 20 gallons per ton of

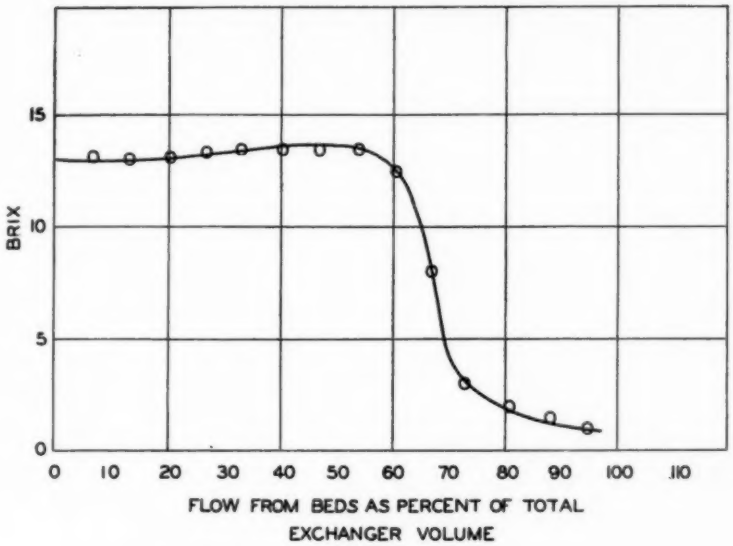

Figure 1.—Sweetening-off.

beets. The suggestion has been made to use the lower Brix sweet water in the battery at the third or fourth cell from the tail end. We do not believe this will bring any savings since water will still have to be used on the tail end of the battery to bring the pulp sugar losses down.

Graph 1 shows the results of sweetening-off on two typical runs. The ordinates show the Brix of the effluent of the pair of cells from the beginning of the sweetening-off step. The abscissae show the volume of effluent expressed as a percent of the volume of the cation plus anion exchanger. The total volume of both exchangers present was 36.5 cubic feet and it had treated juice equivalent to 2.65 tons of beets per average cycle.

The juice to be treated was cooled by passage through a heat exchanger and a cooler in series until it was at 20° to 22° C. The cooling in the heat exchanger was done by means of the treated juice from the de-ionization station with subsequent cooling by cold water in the cooler. In this way some 80 to 85 percent of the heat can be recovered.

No pH correction of the juice leaving the station is needed. The juice at the start of the cycle is slightly alkaline, around pH 9.0, and drops to pH 5 to 6 at the end of a cycle. The resulting mixture when boiled a few seconds gives a solution of pH 7.0 to 7.2. The alkalinity

at the start of the cycle is due to the basicity of the anion exchanger converting traces of unremoved cation salts to the corresponding bases and/or carbonates depending on whether the bed was regenerated with NoOH or Na_2CO_3. The acidity at the end of the run is due to the poor capacity of the anion resins for weakly ionized acids such as H_2CO_3. A short boiling of the juice drives out the CO_2 and the pH rises to around 7.0 to 7.2.

Graph 2 shows the pH of the juice throughout a complete cycle as it leaves the anion cell. The lower line shows the trend of pH as this juice leaves the anion cell. The upper line shows the pH of the juice after it had been degasified to remove CO_2. This degasifying was done at room temperature and, therefore, $C0_2$ was not completely removed. Better removal of CO_2 is accomplished if the juice is boiled. Inspection of the graph 2 will show that the average pH is about 7.0. The explanation of this pH range logically follows when it is realized that an anion exchanger is weakly basic. At the start of a treatment cycle the resin is freshly regenerated and in this state can convert a small portion of the cation salts that leak through the preceding ca-

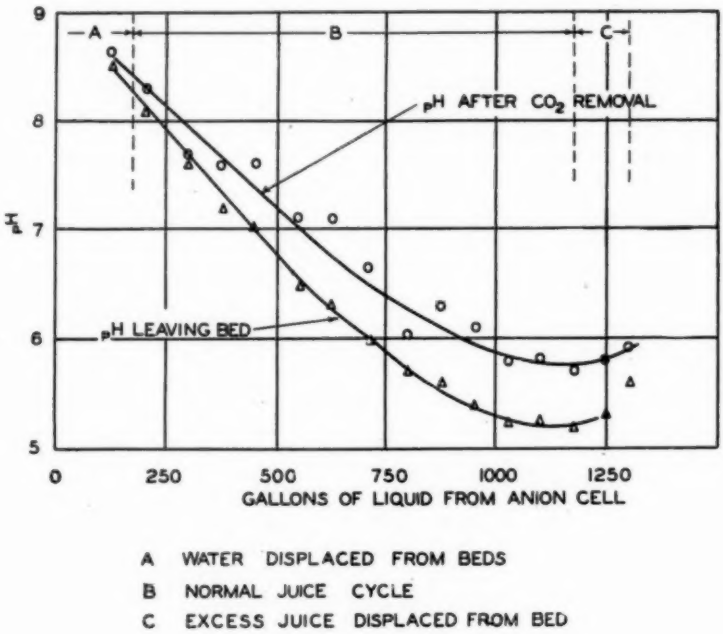

Figure 2.—pH of exchanger juice.

tion cell to bases such as hydroxides or carbonates. The exchanger was previously regenerated with a Na_2CO_3 solution which converted it to the basic form and perhaps to a carbonate base. Now when a trace of unexchanged cation with its anion such as KNO_3 passed through the bed the stronger acid radical NO_3^- would displace the OH^- or $\frac{1}{2}/CO_3^=$ radical from the exchanger and give a basic reaction in the effluent. As the cycle progressed the exchanger would not remove weak acids such as H_2CO_3 and other weak organic acids because as it becomes exhausted its basicity is lowered. Beet sugar juices after second carbonation have as much as 20 percent of their equivalents of anions present as $CO_3^=$ and this with weak organic acids actually leak through and are even displaced from the anion resin by stronger acid radicals towards the end of the cycle. This accounts for the progressive lowering of the pH. The thin juice boiler will remove the CO_2 and raise the pH.

The exchangers, as shown in the table, removed 92.5 percent of the ash constituents in the juice. The overall removal was calculated on the basis of purity increases. On several runs the nitrogen removal was determined by running Kjeldahl nitrogen tests on the juices periodically during the run. On a typical run the average nitrogen removal over the whole run was 90.8 percent. No time was available to determine what specific nitrogen compounds were removed.

The capacities of various exchangers are discussed by Thompson for water treatment. These ratios will hold for sugar solutions within reasonable limits. Certain exchangers exhibit better stability and higher capacity. Certain others can be regenerated to give an equivalent removal and/or capacity with less regenerant consumption. Others give better color removals. The judicious selection of the resinous materials best fitted to all cases is the subject of considerable study upon the part of the Dorr Company, and we are continually testing new exchanger materials as they become available from the various manufacturers.

The acid consumption given in the table 1 is for single stage regeneration. Since that time we have developed methods in our Westport Laboratories that will greatly reduce regenerant requirements.

Additional economics in acid consumption can be realized by operating two more pairs of cells in series. This has two advantages. One is that a cell can be operated to exhaustion instead of breakthrough, which is advantageous since it takes almost as much acid to regenerate the cation cells less completely with less acid and still get good eliminations because the second pair removes what the first pair does not. For example, take a single case of NaCl removal from a solution. With a certain exchanger the cation will remove 96 percent

of the sodium ion when regenerated with 350 percent theoretical acid required to remove the cations on a bed. However, if two pairs are operated in series each cation cell may be regenerated with only 250 percent theoretical to give 80 percent removals and then with two pairs in series there will be an 80 percent removal in each cation cell or an overall removal of 96 percent at a 28.4 percent savings in acid costs.

This series method of operation has, however, some disadvantages also. There has been mentioned the subject of the catalytic inversion of sucrose by the cation exchanger. With two pairs of cells in series this is more than doubled and so makes for a sacrifice in sugar recoveries, and as a result the savings are decreased. In addition it means that in any given installation the number of pairs installed has to be increased by the number of pairs operated in series minus one. Thus first cost of the plant is increased. It is obvious that the advantages and disadvantages of the two methods of operation must be given judicious study.

Table 2 shows the results of boiling and crystallization tests on ion exchange treated sugar juice. These tests were made in cooperation with the Western Sugar Refinery on exchanger treated second carbonation juice from the Woodland factory of the Spreckels Sugar Company. The crystallization steps began with a pilot size pan 30 inches in diameter and ended up in beakers. Manipulative difficulties were severe because after a few crystallizations the removal of samples seriously upset yield figures. However, the results show the purities obtainable in final molasses, although quantities were impossible to calculate with accuracy on the final samples.

To Table 2 is appended a tabulation of a typical refinery blackstrap molasses for comparison. There is quite close agreement on the analysis of the two final products, indicating that the final molasses from an ion exchange plant can be reduced to low purities.

On the basis of numerous tests made on second carbonation juice it is possible to make the following comparison of the estimated recoveries for a straight house versus an exchanger house. The estimates have been made by taking analyses figures midway between the results shown in tables 1 and 2. For an example, a factory slicing 2,000 tons of beets per day with a net sugar to the sugar-end of 16 percent on beets, a feed purity of 90.91 for second carbonation juice, and a finished purity of 97.15 for the ion exchanged juice has been selected. These, as can be seen by inspection of tables 1 and 2, are less attractive economically than those indicated by the maximum purity rises determined in the test work. The intention is to be conservative, although higher purities can be expected with quite a reasonable degree of assurance.

Table 2.—Crystallization tests.

Item	Original 2d carbonation juice	Solution before organolilting	Organolited solution	First filmas	First syrup	Second syrup	Third syrup	Fourth syrup	Fifth syrup	Sixth syrup	Seventh syrup about 7/15/42	Seventh syrup about 10/15/42	Typical refinery blackstrap
R. D. S.	57.0	15.8	14.1	82.5	69.0	67.2	72.4	75.6	78.9	81.4	85.4	82.4	
A. P. C.	.892	.898	.985	.985	.974	.965	.948	.918	.857	.790	....	....	
Total weight	....	....	709.0	121.0	74.59	37.97	18.31	8.46	4.32	1.60	*		
Weight sugar	....	....	98.5	98.5	49.25	24.62	12.59	5.86	2.93	1.03	....		
Weight non sugar	....	....	1.5	1.5	1.28	0.91	0.68	0.53	0.49	0.27	....		
Weight water	....	....	609.0	21.0	24.06	12.44	5.04	2.07	0.90	0.30	....		
Calc. yield of sugar crystals	....	....	....	49.24	24.63	12.03	6 73	2.93	1.90				
A. P. C. of sugar found	....	....	....	.977	.986	....	....	....	....	....	....		
A. P. C. of sugar calc.	.. .	....	....	....	....	.982	.977	.089	.905	....			
ANALYSIS OF SYRUP													
Color		600	17										
pH		7.1	7.0										
Sugar by Polz.	50.200	14.05	13.900	80.60									
True sucrose	....	....	....	....							52.2	42.4	36
Invert	.092	.020	.055	0.26							6.5	7.8	20
Moisture	43.800	84.340	85.830	18.00							14.6	17.6	24
Ash	1.890	.541	.037	0.18							3.2	3.9	8
Raffinose	....	....	....	....							7.6	9.2	....
Organic	4.018	1.049	.178	0.96							15.9	19.1	12
True purity	....	....	....	....							.611	.514	47.4

*NOTE:—Separation of sugar crystals unsuccessful; sample of syrup recovered for analysis and further crystallization on long standing in beakers.

Table 3.—Comparative estimated recoveries.

Per day	De-ionization	Straight
Pounds sugar to sugar-end	640,000	640,000
Purity to sugar-end	90.91	90.91
Pounds non-sugars to sugar-end	62,000	62,000
Pounds raffinose to sugar-end (1 pound/ton beets)	2,000	2,000
Pounds invert former (0.2 percent on sugar)	1,300	300
Purity of juice to pans	97.15	90.91
Pounds sucrose lost in sweeten-off (0.091 percent on sugar)	600	
Pounds non-sugars to pans	15,470	61,700
Pounds sucrose to pans	638,165	639,715
All invert to molasses	1,300	300
All raffinose to molasses	2,000	2,000
Sugar to molasses—1.5 to 1 on NS	23,200	92,550
All non-sugars to molasses	15,470	61,700
Total solids in molasses	41,970	156,550
Pounds molasses at 82 D. S.	51,200	191,000
Net sugar to bay	614,965	547,165
Cubic feet white massecuite	18,400	16,900
Cubic feet hi-raw massecuite	1,500	5,560
Cubic feet lo-raw massecuite	820	2,320
Recovery increase—pounds sugar	67,800	
Molasses decrease—pounds at 82 D. S.		139,800
Percentage recovery on sugar to sugar-end	96.09	85.49

It is realized that calculations of production or extraction from juice purities cannot be as accurately foretold as the estimates indicate. However, both straight house and exchanger house are estimated on the same basis so the comparison is fair.

Table 3 indicates an increased recovery of 67,800 pounds of sugar per day and a decreased production of 139,800 pounds of molasses per day.

Table 4 shows the estimated debits and credits for the two types

Table 4.—Estimated savings with de-ionization based on 100-day campaign.

	Debits	Credits
Increased sugar value at $4.25/100 614,965—547,165		288,150.00
Loss in molasses sales at $18/ton 191,000 pounds—51,200 pounds	125,820.00	
Sulphuric acid at 16 pounds/ton beets 1c/pound	32,000.00	
Soda ash at 13.1 pounds/ton beets 1.4c/pound	36,680.00	
Extra fuel at $6/ton. 15 tons/day	9,000.00	
Extra labor on D-1 station—2 men	4,200.00	
Decreased labor at centrifugals—1 man		1,930.00
No sulphur burned at 1c/pound and 0.5 pound/ton beets		1,000.00
No carbon at 10c/lb. and 0.1 pound/ton beets		2,000.00
No boiling chemicals, estimated		6,000.00
Exchanger replacement at 16 2/3 percent	13,900.00	
	221,600.00	299,070.00
Net savings		77,470.00

Per ton beets $0.3873

of houses with a resulting estimated increased monetary return of $72,470 per 100-day campaign or a net return of $0.3873 per ton of beets. From this return it will be necessary to pay for the plant and pay taxes, insurance, and fixed overhead.

No credit has been taken for the very probably increased value of exchanger molasses nor for the increased efficiency of the sugar-end because of clean scale-free heating surfaces. Molasses prices are now higher than the $18 per ton figure used in calculations, but pre-war prices were considerably lower so the estimated value as taken is thought to be more than fair.

Summary

As a summary it may be stated that an exchanger house promises:

1. Increased recovery of 10.5 percent on sugar processed.
2. Low ash white sugar.
3. Higher operating efficiencies in the sugar-end.
4. Elimination of the use of sulphur and carbon.
5. Elimination of boiling out during campaign.
6. Higher quality final molasses.

This will mean increased financial returns to the sugar processor. The use of the new exchanger process is practical and economic and offers a major technical improvement to the sugar industry.

Grateful acknowledgement is extended to the Amalgamated Sugar Company through whose cooperation on pilot plant tests the greater part of this work was made possible and to the Western Sugar Refinery for the tests on the crystallization of sucrose from ion exchanger treated beet juices.

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Experiments on Beet Seed Sizing and Segmenting

C. W. Doxtator[1]

In the segmenting of beet seed using carborundum stone machines there is a great loss of germinating material. Recently there has been some experimentation with fluted steel wheels in an effort to obtain a greater recovery of both weight and germination from the segmenting process. Likewise, sizing of whole seed before shearing has been attempted for the same purpose.

In order to determine what advantages might be obtained, both in the recovery of seed and in improvement of germination percentage, an experiment was conducted at Rocky Ford, Colo., during December 1944 and January 1945 on sizing of seed before segmenting. Both sized and unsized seed were segmented over a fluted steel wheel and the standard carborundum stone to determine the relative value of seed sizing on these two types of wheels.

Experimental Procedure

Cleaning and Sizing.—The cleaner used was a standard Eureka receiving separator No. 7, with fan shaft speed of 390 r.p.m.

The seed used was American No. 1, Lot 214, which before cleaning germinated 84.6 percent. A 5,587-pound lot of this seed was recleaned over a 7/64 inch round-hole retaining screen with very light air suction. Of the 5,286 pounds recovered, a 3,850-pound lot was sized into three sizes as follows: (1) Between 7/64 and 9/64 inch; (2) between 9/64 and 12/64 inch; and (3) above 12/64 inch. In the sizing operation only a very light air suction, designed to take off dust, was used on the clean seed end of the separator, and all air suction was taken off the receiving end. The remaining cleaned seed, which totaled 1,436 pounds, was held as unsized seed for check purposes.

Segmenting.—Six hundred sixty pounds of the unsized seed was segmented over the carborundum stone and 770 pounds over the fluted steel wheel with the shear bars set at .080 inches. In the sized seed portions, the 7-9/64 inch fraction was not segmented. The 9-12/64 inch fraction was segmented at .080 inch shear bar set, 660 pounds going over the carborundum stone and a like amount going over the fluted steel wheel. In the above 12/64 inch fraction, shear bars were set at .085 inches, with 550 pounds being segmented over the carborundum stone, and a like amount over the fluted steel wheel.

[1]Plant Breeder, American Crystal Sugar Company, Rocky Ford, Colo.

The recovered oversize was resheared at the .080 inch set. Weights of 7-10/64 inch segmented seed recovered, Eureka cleaner discard, (air set at 2.0) and of germs, were recorded for all types seed and both segmenting units. Dust loss was obtained by difference. Germination samples were taken from all recovered seed fractions. All elevation of seed in the experiment was by air suction.

Experimental Results

Cleaning and Sizing.—Percent recovery and germination on the clean seed, sized and unsized, are given in table 1.

Table 1.—Cleaning and sizing; percent recovery and germination data.

Treatment	Seed fraction	Percentage recovery	Percentage germ.	Sprout count per 100 seeds: Singles	Multiples	Total	Abnormal
Original	Normal Whole	100.00	84.6	31.0	53.0	169.5	0.0
Recleaned	Normal Whole	94.61	84.8	23.6	61.0	173.0	0.0
Recleaned seed sizes	7-9/64"	8.75	64.3	33.3	31.0	99.0	0.2
	9-12/64"	57.85	85.0	46.0	39.0	139.5	0.0
	12/64" and above	31.17	91.3	20.5	70.8	211.3	0.0
	Dust	2.23					
	Total	100.00					

Segmenting, Unsized Seed.—Recovery and germination percentages of segmented seed obtained from shearing over the carborundum stone and the fluted steel wheel from unsized beet seed are compared in table 2.

Table 2.—Carborundum stone and steel wheel compared on unsized seed.

Sheared fraction	Percentage recovery	Percentage germ.	Sprout count per 100 seed balls: Singles	Multiples	Total	Abnormal
		Carborundum stone				
7-10/64" sheared	34.9	79.5	52.8	26.8	109.0	6.8
Cleaner discard	4.8	5.8	5.5	.3	6.0	.8
Germs	27.7					
Dust	32.6					
		Steel wheel				
7-10/64" sheared	48.5	68.0	52.3	15.8	81.3	3.0
Cleaner discard	7.4	7.0	6.8	.2	7.3	.5
Germs	24.4					
Dust	19.7					

A much lower percentage recovery and a much higher percentage germination on recovered seed were obtained from the carborundum stone as compared to the fluted steel wheel. The seed obtained from the steel wheel was not recleaned to improve germination; hence it is impossible to say what recovery would have been obtained had quality been raised to the level of that obtained from carborundum

segmented seed. Had this recleaning been done, however, it would be expected, on the basis of previous experience, that a recovery of not more than 45 percent would have been obtained.

The seed obtained from the two segmenting units was carefully inspected in the laboratory both before and during germination. Seed produced by the steel wheel was much more angular in appearance than that from the carborundum stone. Since seed of variable shape is less "drillable" when used in precision planters, the production of seed of this physical quality is not desirable.

Abnormal sprouts appear to be slightly less for the steel wheel than the carborundum stone. This was due to the fact that most of the damaged germs were so badly broken that they failed to show enough sprouting tendency to be called abnormal. Such seed balls were considered as dead in the germination counts.

Segmenting, Sized Seed.—The results obtained from the two wheels used on sized seed are given in table 3. In this part of the experiment only the 9-12/64 inch size and the above 12/64 inch size were sheared, but the unsheared 7-9/64 inch size has been included in recovery percentage. Data are given on a "sack run" basis.

Table 3.—Carborundum stone and steel wheel compared on sized seed.

Sheared fraction	Percentage recovery	Percentage germ.	Sprout count per 100 seed balls			
			Singles	Multiples	Total	Abnormal
		Carborundum stone				
7-10/64" sheared	48.8	75.5	53.2	22.4	100.8	4.9
Cleaner discard	2.5	4.3	3.9	1	4.0	.1
Germ fraction	22.2					
Dust (by difference)	26.0					
Total	100.0					
		Steel wheel				
7-10/64" sheared	54.8	70.5	49.5	21.1	96.5	4.6
Cleaner discard	5.0	5.0	4.0	.7	4.1	1.4
Germ fraction	21.2					
Dust (by difference)	18.9					
Total	100.0					

Recovery of seed in this test is in favor of the steel wheel, but percentage germination is higher for the carborundum stone segmented seed. As previously noted, seed segmented over the steel wheel was more angular than carborundum stone seed. In this test, steel wheel segmented seed was slightly lower for single sprouts, multiples, and total sprouts than seed from the carborundum stone.

In order to show the effect of each segmenting wheel on each of the sizes of seed sheared, the recovery and germination data obtained

for each of the seed sizes 7-9/64 inch, 9-12/64 inch, and above 12/64 inch, are set up in table 4.

From these data it will be noted that greater recoveries of seed were obtained from the 9-12/64 inch size than from the above 12/64 inch size for both segmenting wheels; and that germination percentage, multiple sprout count, and total sprout count were higher for segmented seed obtained from the smaller sized seed. The large whole seed gave a segmented product higher in single sprout count and in number of abnormal sprouts per 100 seed balls tested, indicating that even at .085 inch shear bar setting for this size, and a setting of .080 inch for the oversize, appreciably greater damage was done to the larger seed than to the 9-12/64 inch at the .080 inch shear bar setting. It appears that shear bar spacing should be wider than .085 inch for seed above 12/64 inch size, allowing for a greater oversize volume to be obtained and this in turn reduced to the 7-10/64 inch size by successively closer spacings. The 7-9/64 inch size was not segmented, but it is likely that a small amount of damage would have been obtained if this seed had been segmented.

In the comparison of the segmenting wheels, it is evident that the steel wheel was more damaging to the larger size whole seed than the carborundum stone. For this large whole seed size, the recovery is only 2.9 percent higher for the steel wheel, but this seed germinated 61.0 percent as compared to 74.3 percent germination for the carborundum stone.

Seed Sizing Effects.—From the information on presizing of seed for the two segmenting wheels given in tables 2 and 3, pertinent data have been extracted and placed in table 5 for direct comparison of presizing results.

For both segmenting wheels, an appreciable improvement in recovery was obtained from presizing of seed. The percentage improvement was, however, much greater for the carborundum stone than for the steel wheel, being 13.9 percent and 6.3 percent, respectively. It is noted that germination percentages did favor the sack run segmented seed from the carborundum stone over the presized seed. It appears that, for unknown causes, air suction on the separator was somewhat more efficient on this test run than on the presized seed run. Consequently, it must be assumed that the recovery of 34.9 percent for sack run seed is slightly lower than should have been obtained, but despite this, the improvement in recovery due to presizing will still favor the carborundum stone over the steel wheel.

Capacities.—In all milling operations, capacity of equipment is important. Checks were made on the capacity of both segmenting wheels for the two sizes 9-12/64 inch and 12/64 inch and above. Results are given in table 6.

Table 4.—Recovery and germination data obtained from all sizes of seed using two types of segmenting wheels.

	Carborundum stone						Steel wheel					
			Sprout count per 100 seed balls						Sprout count per 100 seed balls			
	Percentage recovery	Percentage germ.	Single	Multiple	Total	Abnormal	Percentage recovery	Percentage germ.	Single	Multiple	Total	Abnormal
7-9 seed size												
Sheared fraction	100.0	64.3	33.3	31.0	99.0	0.2	100.0	64.3	33.3	31.0	99.0	0.2
9-12/64″ seed size												
7-9/64″ original*	46.8	79.8	55.8	24.0	106.8	5.5	55.5	76.0	52.8	23.3	105.8	5.0
7-10/64″ sheared	2.0	5.5	5.5	0.0	5.5	0.0	5.4	4.3	4.3	0.0	4.3	2.0
Cleaner discard	23.2						20.0					
Germ	28.0						19.1					
Dust												
Total	100.0						100.0					
12/64″ and above, seed size												
7-10/64″ sheared	38.0	74.3	61.8	12.5	88.3	7.3	40.9	61.0	52.3	8.7	71.3	6.8
Cleaner discard	4.2	3.3	3.0	.3	3.5	.3	5.8	6.3	6.0	.3	6.5	1.0
Germ	28.2						29.5					
Dust	29.6						23.8					
Total	100.0						100.0					

*Not segmented.

Table 5.—Comparison of sack run and presized seed in the production of segmented seed from two segmenting wheels.

Seed size	Seed treatment	Percentage recovery	Percentage germ.	Sprout count per 100 seed balls: Single	Multiples	Total	Abnormal
		Carborundum stone					
7-10/64 recovered	Sack run	34.9	79.5	52.8	26.8	109.0	6.8
	Presized	48.8	75.5	53.2	22.4	100.8	5.0
		Steel wheel					
7-10/64 recovered	Sack run	48.5	68.0	52.3	15.8	85.3	4.9
	Presized	54.8	70.5	49.5	21.1	96.5	4.6

Table 6.—Capacity of two segmenting wheels on two sizes of seed.

Seed Size	Pounds seed segmented	Carborundum wheels: Time in minutes and seconds	Carborundum wheels: Pounds capacity per hour	Steel wheel: Time in minutes and seconds	Steel wheel: Pounds capacity per hour
9-12/64"	660	23.05	1,718	16.48	2,354
12/64" and above*	550	23.01	1,434	15.49	2,086

*Shear bars set at .085 inch until all seed segmented, oversize seed segmentd at .080 inch.

Summary and Conclusions

In this experiment the carborundum stone segmenting unit when used on sack run seed gave a recovery of 34.9 percent of 7-10/64 inch segmented seed as compared to 48.5 percent for the fluted steel wheel. Germination percentage was 79.5 for the stone and 68.0 for the steel wheel.

On sized whole seed the carborundum stone unit gave a recovery of 48.8 percent of seed germinating 75.5 percent; and the steel wheel gave 54.8 percent recovery of seed germinating 70.5 percent.

Better recoveries and germination percentage of segmented seed were obtained from the 9-12/64 inch size over the 12/64 inch and above size. For the carborundum stone this amounted to 8.8 percent in recovery and 5.5 percent in germination. For the steel wheel this amounted to 14.6 percent and 15.0 percent, respectively.

Much more uniform seed segments were obtained from the carborundum stone in all tests.

Hourly capacity for the steel wheel was much greater than for the carborundum stone.

From this investigation it is concluded that sizing of whole seed before segmenting offers a chance of immediate improvement in seed recovery; and that further experiments on various types of fluted steel wheels are necessary before final evaluation of this segmenting equipment is made.

Processing Sheared Seed

R. S. LAMBDIN[1]

The Spreckels Sugar Company will use for the 1946 season a shearing machine similar to the Bainer type machines; however, the Spreckels shearing plants will be equipped with steel wheels instead of grit. The steel wheel has been very satisfactory in its performance in that a setting remains constant and wear is very slow. A small rock passing over a grit wheel causes sufficient damage to change shearing performance, whereas 200 sacks of seed which contained enough rocks per sack to ruin a grit wheel were sheared in 1945 with a steel wheel before it was necessary to replace the wheel.

Because of the size of seed being sheared by the Spreckels machines in general it has not been necessary to grade seed prior to shearing; however, some grading is being done in order to improve germination prior to shearing. The present shearing wheels have a capacity of approximately 1,000 pounds of whole seed per hour, which is considerally greater than the cleaning equipment can handle.

Steel Wheel Specifications

Diameter	9⅜ inches
Face	6⅛ inches
Shaft	1¼ inches
Rim	⅜ inches thick case hardened
Divisions	236
Pitch	.1248 inches
Speed	750 r.p.m.

Milled with a 60° miller with vertical face 1 inch ahead of center line blank.

Cleaning Procedure

All sheared seed is screened through a number H-442 Crippen cleaner. Overrun seed is resheared to meet the desired size. Following the normal cleaning operation the sheared seed is elevated and dropped into an aspirator to facilitate further cleaning and improve germination. Table 1 demonstrates some improvements of germination by use of an aspirator. Two varieties of seed were used in this test at various shear-bar settings.

The aspirator is limited in its ability to improve extremely low germinating lots. In some lots of seed merely re-running them through the aspirator has improved the germination from 2 to 5 percent.

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[1]Spreckels Sugar Company, Spreckels, Calif.

Table 1.—Aspirator results for improvement of sheared seed.

Wheel settings, inches		Percentage cleaner loss	Percentage aspirator loss	Final recovery	Soil germination tests*	
					Before aspirator	After aspirator
U.S. 15	.085	25.00	4.42	70.58	87.25	91.75
	.080	31.25	5.42	63.33	86.50	88.25
	.078	34.50	6.00	58.90	83.50	87.75
	.075	37.25	6.27	56.48	81.00	88.25
	.073	46.25	10.75	43.00	76.75	87.25
	.070	51.50	8.78	39.72	71.00	84.50
U.S. 33	.092	32.00	3.70	64.30	83.50	86.25
	.088	35.50	7.40	57.10	80.50	86.25
	.084	38.00	8.50	53.80	80.25	88.00
	.080	44.50	9.20	46.30	72.75	83.50
	.078	44.50	10.00	45.50	71.25	85.50
	.070	49.00	9.80	41.20	65.00	79.00

The germination of whole seed was U.S. 15—95.00, U.S. 33—93.00.
*Injured seedlings were not considered in the germination counts.

During the 1945 season 258,454 pounds of whole seed was sheared by one of the Spreckels machines. This seed was all sheared with a steel wheel and then passed through a cleaner and an aspirator. The final recovery of this seed was 57.15 percent with an average germination of 84.21 percent. The average seedlings per unit was 1.38. All this seed was run in 20-bag increments and germination tests conducted on the final seed recovered from the 20 bags of whole seed. Germination tests made at Spreckels were conducted in soil or on blotters and in no case were injured seedlings included in the germinating percentage.

Seed Standards

Because of the types of planters used in the Spreckels Sugar Company's districts it has been necessary to make available three classes of prepared seed:

1. Normal whole seed sheared and screened through a 10/64 and over 7/64 screen. This product will be used on a rather large portion of the acreage and planted primarily with a Planet Jr. planter. The recovery of this class of seed is about 55 percent of the original.

2. Normal whole seed graded through an 11/64 and over an 8/64 screen. The seed passing over the 11/64 screen is sheared very lightly and then blended into the final product. The recovery of this class is approximately 70 percent of the original seed.

3. Normal whole seed sheared and screened through a 9/64 and over a 7/64 screen. This product is produced on a very small scale to accommodate a few Cobbly planters. The recovery of this class is 30 to 40 percent, and maintaining high germination is difficult.

All lots of seed handled must germinate 80 percent or more prior to issuing. Shearing at Spreackels plants is based on obtaining 1.25 to 1.40 seedlings per unit and not to exceed 1.50 seedlings per unit.

Based on the types of planters generally used and the wide variance that we encounter in field emergence it has not been necessary to attempt to secure an extremely high degree of singleness. Uniform seed of high germination planted at a moderate rate of seeding has given enough singleness to make hand thinning much easier than with the original normal seed plantings.

Methods Used and Results Secured from Pelleting of Sugar Beet, Vegetable, Flower, Tree and Other Field Crop Seeds

VOGELSANG, P; SCHUPP, A. A.; REEVE, P. A.

The pelleted seed program of the Farmers and Manufacturers Beet Sugar Association was initiated in the late summer of 1943 in cooperation with the Dow Chemical Company, Midland, Mich. In August 1944 the entire project was taken over by the Association but we continued to use Dow facilities at Midland and Dow personnel loaned for this purpose.

The first objective of the pelleting program was to perfect a process for making a round, smooth pellet of uniform weight from the irregular segmented seed with the hope of facilitating precision planting. One condition was that these pellets were to be made of materials which would readily break down when placed in contact with soil moisture and should not interfere with normal germination of the seed.

This first objective was accomplished by the use of a rotating pan similar to those used by the pill and candy manufacturers for coating their products. The segmented seed was placed in the rotating pan and by alternate wetting with an adhesive material and dusting with an inert material was gradually built up to the desired spherical smooth pellet. We have found that methyl cellulose, a water-soluble plasticide, is the best binder. The best inert base found to date is a combination of 65 percent feldspar and 35 percent flyash. The feldspar used initially is screened through a 40-mesh screen; for the finish coat it is screened through a 200-mesh screen. The flyash, which is the ash obtained from the burning of powdered coal in large boiler installations, is screened to a similar size. It has been found that a light finish coat of fine amorphous graphite reduces the friction in a planter and greatly reduces the amount of breakage in the planter.

The possibility of adding fungicides, fertilizers, insecticides, repellents, starting agents, hormones, etc., to the coating material for the control of seedling diseases and soil-borne insect pests, as well as to improve the vigor and growth of the seedling, was next explored. A large number of fungicides were tried in varying quantities and varying combinations. In table 1 are listed those fungicides and the optimum amounts of each which have proved best under our conditions. In figure 1 are shown the result of toxic runs on fungicide amounts and the maximum amount which may be used without injury to germination under normal conditions. The addition of superphos-

Table 1

	Date made	Pan size	Old feldspar from	New feldspar	Flyash		Semesan	Semesan Bel	Yellow Cuprocide	Red Cuprocide	Ceresan	Chlornil	Super-phosphate	Fertilizer mix
363- 1-D	8-24-45	Large		65	35							10	3	
364- 1-D	8-24-45	Large		65	35				10				3	
365- 1-D	8-27-45	Large		65	35	5							3	
366- 1-D	8-27-45	Large		65	35	10							3	
399- A	6-13-43	Small	65		35				5				10	
399- 1-D	8-27-45	Large		65	35				5				10	
418- 1-D	9- 4-45	Large		65	35	10							10	
420- 1-D	9- 4-43	Large		65	35		1						3	
421- 1-D	8-25-45	Large		65	35		5						3	
421- 3-D	9- 5-45	Large	65		35		5						3	
478- 1-D	9- 5-45	Large		65	35		1						10	
503- 1-D	9- 5-45	Large		65	35				5					10
541- 1-D	8-24-45	Large		65	35	5			5				10	
543- A	8-24-44	Small	100			10							10	
543- 3-D	9- 6-45	Large	100			10							10	
546- 1-D	8-25-45	Large		100					2				3	
563- 1-D	8-25-45	Large		100					10			20	10	
574- 1-D	8-27-45	Large		100				2					10	
603- 1-D	8-27-45	Large		100							½	10	5	
610- A	9-29-44	Small	100							3		10	5	
610-42-D	8-25-45	Large	(Clay base)							3		10	5	
610-43-D	8-13-45	Large	(Graphite base)							3		10	5	
676- 1-D	8-30-45	Large		100				2			(a)	5	5	
702- 1-D	9- 4-45	Large		100		1		2					10	
723- 1-D	8-30-45	Large		100				2			(b)		5	

(a) Also 400 p.p.M. phenolbarbitol
(b) Also 10 percent brewers yeast

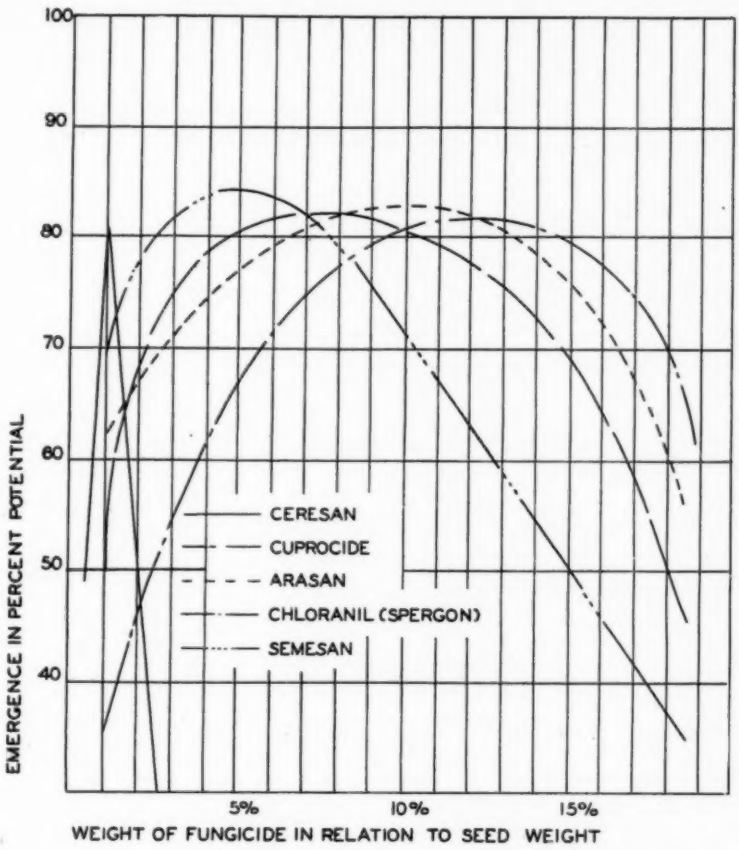

Figure 1.—Optimum range for various fungicides. The addition of fertilizer to the pellet generally reduces the amount of fungicide which can be added.

phate at the rate of 10 percent of the weight of the seed has given the best results as far as fertilizers or a combination of fertilizers are concerned. Plant stimulants and hormones have proved beneficial under certain conditions. As far as insecticides and repellents are concerned, we have determined the toxic maximum but have very few actual field results.

Table 2 shows the effect of various factors upon the resulting pellet.

Table 2.—The effects of various factors upon the resulting pellets.

	Index of emergence with best net emergence as 100
A. Results of test comparing feldspar base with a flyash-feldspar base in large and small pan	
Treatment	
1. Flyash-feldspar base made in large pan	100
2. Flyash-feldspar base made in small pan	100
3. Feldspar base made in small pan	99
4. Feldspar base made in large pan	87
B. Results of test comparing pellets made with a feldspar and feldspar-flyash base in combination with superphosphate and fertilizer mix (2-5-5)	
Treatment	
1. Flyash-feldspar base with superphosphate	100
2. Flyash-feldspar base with fertilizer mix	94
3. Feldspar base with fertilizer mix	91
4. Feldspar base with superphosphate	89
C. Results of test comparing pellets containing superphosphate and fertilizer mix (2-5-5)	
Treatment	
1. 10 percent superphosphate	100
2. 10 percent fertilizer mix	92
3. 5 percent fertilizer mix	92
4. 5 percent superphosphate	87
D. Results of tests to determine effects of location of fertilizer in pellet	
Treatment	
1. Fertilizer mixed in 1/3 of base, applied first	100
2. Fertilizer mixed in all of base	90
3. Fertilizer mixed in 1/12 of base, applied first	88

Pellets of each batch are stored for two years. A pellet that has proved satisfactory when first made is further tested every 3 months to determine the effect of pelleting on the storage of the seed.

Each pellet is tested under the following conditions:

a. In flats in a cool room.

b. In flats in a greenhouse (controlled temperature).

c. In a root cellar under damp humid cool and poor light conditions.

d. Outdoors, hand planted.

e. Outdoors, machine planted.

Tests are made both in good sugar beet soil and in soil taken from an area where black-root continually occurs. Each report is the average of several replications. A daily record is kept of all tests in order to determine the rate of emergence and extent of post-emergence damping off. Every fourth row is a row of check seed. All data are calculated on the following basis:

a. Net Emergence Index. The net emergence of the pellet after deducting for post-emergence damping off divided by net emergence of the check seed after deducting for post-emergence damping off.

b. Rate of Emergence Index. The net emergence of the seed or pellet on the seventh day divided by the net emergence on the fourteenth day is calculated as the "rate of emergence." The rate of emergence of the pellet divided by the rate of emergence of the check seed is called the "rate of emergence index."

In explanation of the above, following are some results from good and poor pellets tested in the late summer of 1945:

Pellet No.	399-A	610-43-D	570-1-D
Date made	6/13/43	8/13/45	8/25/45
Net emergence index	194	219	71
Rate of emergence index	115	72	51

No. 399-A, pelleted 2 years before the test, produced almost twice as many seedlings as did the check and emerged at a faster rate than the check. No. 610-43-D produced more than twice as many seedlings as did the check; the rate of emergence was slower on the seventh day, but by the tenth day the net emergence of the pellet had exceeded the net emergence of the seed. No. 570-1-D was poor both as to emergence and rate of emergence. Table 3 shows results of some of the better pellets.

Various vegetable, flower, field crop, and tree seeds have been pelleted. Although the amount of time devoted to these crops has been limited, remarkable results have been obtained with certain crops. In tomatoes, a test of pelleted seed vs. 8-inch transplants showed as great a production from the seed as from the transplants.

Our pelleting experience to date indicates that:

1. Most irregular seeds can be pelleted to a uniform size and weight, and when the proper binder and base are used that the pelleting does not hinder germination under normal conditions.

2. Net emergence and livability can be increased by the incorporation of proper amounts of fungicides, fertilizers, and starting agents.

3. Because of more uniform size and increased weight, the pellet can be more accurately planted than the uncoated seed.

Table 3.—Selected results from outdoor field test 1945 counts on rows of 100 feet, four replications.

	Net emergence index						Net emergence in percentage potential	
	First count		Second count		Third count		Third count	
	Hand planted	Machine planted	Hand planted	Machine planted	Hand planted	Machine planted	Hand planted	Machine planted
363— 1-D	112	113	144	131	177	172	60.02	52.20
364— 1-D	148	147	184	158	266	194	77.28	59.77
365— 1-D	65	70	114	148	171	151	57.86	45.86
36— 1-D	80	113	125	136	162	173	62.18	56.06
390— A	190	211	174	191	186	213	77.64	75.05
390— 1-D	67	79	131	120	161	164	61.78	53.16
418— 1-D	91	73	230	128	251	152	84.74	51.23
420— 1-D	23	33	123	90	137	144	60.02	47.54
421— 1-D	8	48	105	112	113	169	49.29	55.71
421— 3-D	24	37	119	98	134	133	58.45	44.02
478— 1-D	72	87	130	117	154	169	61.59	55.45
503— 1-D	110	52	131	104	151	130	60.61	42.71
541— 1-D	155	122	161	131	172	155	57.67	50.49
543— A	189	119	184	121	191	148	69.82	61.73
543— 3-D	143	80	131	106	164	120	55.51	47.71
546— 1-D	151	148	134	162	163	155	54.92	61.52
563— 1-D	111	80	127	123	159	140	53.75	55.54
574— 1-D	45	62	170	114	169	116	51.78	56.59
603— 1-D	38	66	161	107	165	111	50.41	51.76
610— A	....	65	141	144	155	157	83.05	44.75
610—42-D	31	92	214	146	231	168	54.33	59.75
610—43-D	107	144	270	161	264	283	66.69	62.39
676— 1-D	188	100	120	163	130	174	56.30	63.54
702— 1-D	12	32	73	131	95	142	41.00	52.29
723— 1-D	7	38	143	136	159	148	55.51	52.02
Average							60.89	54.71
Average of checks							36.36	35.09

Note: In the above index the net emergence of each pellet is compared to the net emergence of its adjacent check, not to the average emergence of all checks.

4. Pelleting does not add materially to the cost when done on a production basis. If pelleting increases the net emergence to the point where the individual seed spacing can be increased, pelleted seed will cost less per acre than uncoated seed.

5. The incorporation of fungicides in amounts greatly in excess of the amount recommended by the fungicide manufacturer is necessary for the control of pre-emergence and post-emergence damping off.

6. Pelleted sugar beet seed will germinate in dry soil as readily as its corresponding uncoated check.

7. Under normal germinating conditions, the rate of emergence of pelleted and unpelleted seed is the same; under cool conditions,

the emergence of the pellets may be retarded several days.

8. The incorporation of growth-promoting substances may prove very beneficial.

9. Repellents and insecticides such as DD and DDT up to given amounts do not interfere with normal germination of the seed or cause injury to the seedling.

10. The incorporation of 10 percent superphosphate in the pellet gives better results than other fertilizers or combinations of fertilizers.

11. A combination of fungicides may prove better than any one specific fungicide.

12. A light coating of graphite on the pellet as a final coating improves planter performance and does not interfere with normal germination.

13. There is a possibility of controlling diseases which appear after the seedling stage. Incorporating Arasan on onion seed in an amount equal to its weight prevents onion smut.

14. Minor elements that are lacking in soils can be added in the pellets.

15. The pH of the pellet can be varied to give the proper pH for optimum germination of any given seed.

16. Much work still remains to be done in the pelleting of field crops seeds. Pelleting may be another source of combating new seedling diseases which might attack our field crops in the future.

Patent applications on the process are held by the Farmers and Manufacturers Beet Sugar Association.

Segmenting and Processing Sugar Beet Seed

E. W. SHANNON[1]

Segmenting beet seed to obtain maximum quality and germination with minimum loss presents a tremendous problem to the seed plant operator. In this report I would like to present some of the problems confronting the operator and pass on to you experiences we have had in the past for possible mutual benefit.

The Great Western Sugar Company has set a standard of 70 percent germination, 60 percent singles, and a minimum of 30,000 seed balls per pound on segmented seed issued to farmers. All segmented seed is graded 7/64 to 10/64. In the germination laboratory all abnormal plants resulting from injury in the segmenting process are counted as non-germinating. We feel that this standard gives us a product of high quality for present planting equipment. Higher standards will be desirable when precision planters are perfected.

Pregrading of Seed and Its Effect on Segmentation

Theoretically, pregrading of whole seed before segmentation would be very desirable; small whole seed passing through the 10/64 screen would be added to the segmented large seed. Screen tests on two varieties of seed to be segmented this year were made at each seed plant to find the range of seed sizes and determine whether the small whole seed passing through the 10/64 screen could be added to segmented seed coming from the segmenting units. The results obtained from the small whole seed (7/64 to 10/64) are given in table 1.

Table 1.—Results with small whole seed.

Factory	Kind of seed	Percentage germination	Percentage singles	Percentage of total
Billings	US 33	88.5	38.7	54.5
	GW 59	76.3	67.1	19.2
Sterling	GW 59	55.2	66.9	30.9
	GW 34	35.1	72.3	30.4
	GW 67	57.6	53.1	15.7
Scottsbluff	GW 59	59.7	45.7	13.6
	GW 87	49.8	68.4	24.2
Longmont	GW 59	48.4	83.9	12.9
	GW 49	62.0	59.7	15.3

[1]Seed Processing Department, Great Western Sugar Company, Longmont, Colo.

This table shows that each type or variety of seed presents a different problem in processing. The GW 59 located at Billings was the only seed meeting the standard of 70 percent germination and 60 percent singles. Some of the varieties represented would require segmentation to produce the desired singles or a greater loss in recovery of the larger seed when segmented would be necessary to offset this difference. Seed with low germination and a high percentage of singles could be built up to the standard by gravity table work. Low germinating seed such as the GW 34 located at Sterling would give a low recovery from the gravity table.

The following preliminary test on pregrading and segmenting was conducted at Longmont. One hundred bags of GW 49 were graded into small whole (7/64-10/64), medium whole (10/64 to 12/64), and large whole (12/64 to 19/64). The small whole seed was run over the gravity table to bring the germination to standard as the seed was graded.

Table 2.—Results of grading (11,100 pounds of seed introduced).

	Pounds	Percentage of total	Percentage germination	Percentage singles
Large seed recovered	3,857	34.75	90	
Medium seed recovered	3,984	35.89	72	
Small seed recovered	2,295	20.68	83	56
After gravity separation				
Loss	964	8.68		

The loss reported is rather large and is attributed to loss of small seed from gravity separation, dust and trash removed, and filling of elevator boots.

The medium and large grades of seed were segmented separately with the following results:

	Introduced	Segmented recovered	Percentage recovery	Percentage germinated	Percentage singles
Medium	3,984	2,170	54.47	74	56.8
Large	3,857	1,745	45.24	78	50.6

Combining the small whole, medium segmented, and large segmented gave a total of 6,210 pounds or 55.95 percent recovery of the original total, with a probable germination of 78.4 percent and 55.1 percent singles.

Fifty bags of the seed was segmented from the stack without grading for comparison. Results follow:

Introduced	Segmented recovered	Percentage recovery	Percentage germination	Percentage singles
5,550	2,500	45.05	74	66.9

Summary

Pregrading in this test gave an increase in recovery of 10.9 percent; the final mixture would fail to meet germination standards for percentage singles. To meet this standard, lower total recovery would be necessary. Germination results of the ungraded seed indicate an increase in recovery would meet the germination standard. On this basis, pregrading of this variety of seed would not increase recovery materially.

Segmenting of beet seed is primarily a reduction in the size of the seed ball to pass through the 10/64 screen and remain on the 7/64 screen, in this reduction we expect the seed ball to break along lines of cleavage, producing as many single germ seed units as possible. Large seed requires a greater reduction in size and results in lower recovery.

Small whole seed from varieties used in segmenting should be tested for germination and mixed with the larger seed as it is segmented if germination results indicate this process is feasible.

Types of Segmenting Devices and Their Effect Upon Quality of Product and Recovery

Two types of segmenting units are used in the Longmont plant, the original California type (Bainer), and a double wheel unit. Two changes were made on the California machine last year, resulting in increased capacity and quality of product. The shear bar was lowered 1 inch below the center of the stone and the hopper was rebuilt to utilize the full cutting edge of the shear bar and is adjustable for distance from the stone. Strips of carbaloy have been inserted in the shear bar for use this year, eliminating frequent changing of this bar.

The double wheel unit has two stones rotating in the same direction. One stone revolves at 880 r.p.m. the other at 18 r.p.m. The fast wheel is mounted on a stationary shaft and the slow wheel is adjustable for distance between the stones. The hopper is constructed to utilize the full surface of the stones. A general comparison of these two units on the following points follows:

Shearing Effect.—The California unit has a definite cutting effect upon the seed as it is forced between the stationary shear bar and the stone; as a result many seed units are flattened.

The double wheel unit has more of a crushing effect upon the seed. The slow wheel acts as a movable shear bar and rotates the seed as it passes through the opening between the stones; as a result the seed units are rounded.

Discard or Trash.—Trash from the California type unit is more finely ground with a large percentage of dust. More cork remains on the seed from the double wheel unit.

Return (Seed passing over the 10/64 screen and reintroduced to the segmenting units).—Return from the California type unit is definitely greater because more of the seed is flattened in the shearing process, making the seed less adaptable for screening.

Adjustment.—The double wheel unit is more sensitive to adjustment and requires more frequent checking.

Recovery.—Recovery from the double wheel unit is slightly greater when set to produce the same germination. This point will be tested further for final analysis.

Screen Sizes.—Seed from the double wheel unit is larger than that from the California type.

Capacity.—The California type unit had a greater capacity by 30 pounds of whole seed per hour on one comparative test.

Germination and Percentage of Singles.—Tests indicate from 2 percent to 6 percent greater singles from the double wheel unit when settings are made for the same germination.

Table 3 gives comparative results of recovery, percent germination, percent singles, and screen size of the final product. Whole seed used in this test germinated 71.5 percent.

Table 3.—Results with California type unit.

Recovery setting	Percentage Germ.	Percentage singles	Size of seed in percentage of total		
			10/64-9/64	8/64-7/64	9/64-8/64
60.3	66	62.8	15	43	42
66.4	68	61.8	29	40	31
68.7	68	60.3	33	29	28
		Double wheel unit			
60.0	57	69.3	22	49	29
60.8	57	72.8	38	41	21
63.0	62	72.6	40	40	20
64.0	56	65.2	42	45	13
68.0	67	60.4	44	39	17
70.0	66	66.7	44	39	17

Grading and Cleaning of Segmented Seed

Seed from the segmenting units is screened over a Clipper Cleaner (Model—Super 29 D). The combination of screens used are 10/64, 6/64, 8/64, and 7/64. Seed passing over the 10/64 screen is reintroduced to the segmenting units for further sizing; germ material passing through the 6/64 screen is sold for livestock feed. Seed passing through the 10/64 screen and remaining on the 7/64 screen is run over the gravity table to bring the germination up to standard. Everything through the 7/64 screen is discarded. In segmenting seed of low germination, we remove all the low germinating seed possible by air adjustments on the Clipper; this makes it possible for a better separation on the gravity table.

Gravity Table.—In 1945 the gravity table was used in three of the plants producing segmented seed for the Great Western Sugar Company. The purpose of the gravity table in our operation is to produce the 70 percent standard of germination.

Maximum results are obtained from the gravity table when all adjustments are working in perfect harmony with each other. These adjustments include lateral slope, longitudinal slope, lower air blast, upper air blast, rate of feed, and rate of oscillation. At Longmont we have found that a longitudinal elevation of 2½ inches and a lateral elevation of 1½ inches gives good results in most cases; however, these elevations are changed as the need arises. Using this as a base to work from, adjustments of air blast, rate of oscillation, and rate of feed are used to give the proper distribution of seed over the table. We rely entirely upon the "starch test" in setting this machine, preliminary germination tests give a fairly accurate difference to expect from the "starch test" and the actual germination.

Seed from the lower end of the table having a germination of 10 to 15 percent is discarded. If it is necessary to remove a portion of the seed from the center section of the table to secure the desired germination on the upper end, this seed is re-run over the table with different adjustments and later blended with other seed.

Most varieties of seed react quite favorably to gravity separation. Segmented seed gives better results than whole seed because of less resistance to the air blasts as a result of removal of the cork. In our operation here I feel we have experienced both extremes for separation. One particular variety would not respond favorably to gravity separation as whole seed or as segmented seed, regardless of adjustment.

Aspirators.—Aspirators were used at Sterling, Colo., and Billings, Mont., last year. My experience with an aspirator was on an

experimental basis 2 years ago, the results of which were quite gratifying.

New Methods of Seed Processing

Decortication and Burr Reduction.—During the summer a number of lots of whole seed low in germination were reprocessed to build up germination by gravity table separation for use in segmenting this winter. Some lots of whole seed do not respond to gravity separation favorably because of an excessive amount of cork which offers a high resistance to the air blasts of the gravity table. Decortication or burr reduction would be very desirable in processing seed of this character. To accomplish burr reduction, seed was put through the double wheel segmenting unit, using an opening between the stones that would let the larger seed pass through without breaking the seed ball. The contact of the seed on the stones resulted in burr reduction which definitely improved the performance of the gravity table. Light seed low in germination was pulled off by the clipper cleaner fans before it entered the gravity table. An example of the work done follows (Seed used was GW 94, California production, having a germination of 43 percent):

Seed introduced	Seed recovered	Percentage of total recovered	Percentage germination
974	625	64.3	66

Germination of seed discarded by gravity table ..... 26 percent
Grmination of seed discarded by clipper cleaner ..... 25 percent

Results of other lots of seed processed in the same manner were quite comparable to this test. In using the double wheel segmenting unit for decortication or burr reduction we realize the larger seed is affected more than the smaller and that it is not a perfect method of decortication. Results indicate decortication by improved methods would be very desirable when germination of whole seed must be raised by the gravity table or aspirator.

Preliminary tests in segmenting decorticated seed indicate a high recovery.

The Use of Pregraded Whole Seed and the Gravity Table in the Preparation of Segmented Sugar Beet Seed

FORD T. SCAILEY[1]

The problems confronting the processor of segmented seed differ in many respects. The germination of the whole seed, its size range, and the proportion and germination of each individual size range vary considerably. There is, likewise, a difference in the desired size range, germination, flowability, and percentage of single germ seed segments of the end product. Variation in these factors necessitates certain changes in processing methods. It is because of these factors that any or all processing methods may or may not work out satisfactorily in all cases.

The factors involved in our operations at St. George, Utah, are as follows: The desired product is a seed of a size range commonly referred to as 7/64 to 9/64 seed. Actually the size range of this product could be better defined as 6.50/64 to 8.50/64 seed. Approximately 15 percent of this product is minus 7/64; 65 percent is from 7/64 to 8/64; and 20 percent is plus 8/64. The processing required after the segmented seed has been graded brings about a further reduction in size. This seed is for use in precision planters and must of necessity be a standard product because the cell dimensions of the Cobbley rotors were designed for a seed of the afore-mentioned size range. A larger proportion of minus 7/64 seed reflects itself in doubles planted and a high breakage index. Likewise a larger proportion of plus 8/64 seed would hinder proper planter performance. The desired germination is 90 percent with approximately 90 percent singles. The desired qualities are deemed to be of sufficient importance to maintain regardless of recovery.

The whole seed to be processed has in our case been almost entirely U. S. 22 and U. S. Improved 22. The whole seed product has been very uniform and of high germination (approximately 90 percent). This seed will range in size from 7.50/64 to plus 15/64. A 16-hour composite of the whole seed introduced was analyzed to determine seedlings per seed ball and total germination. These data are shown in table 1. The germination figures are shown on the three sizes that are segmented. The percentage of each size is also shown.

It is of interest to note in this table that the percentage of singles is not always the true indication of the value of any given lot of seed

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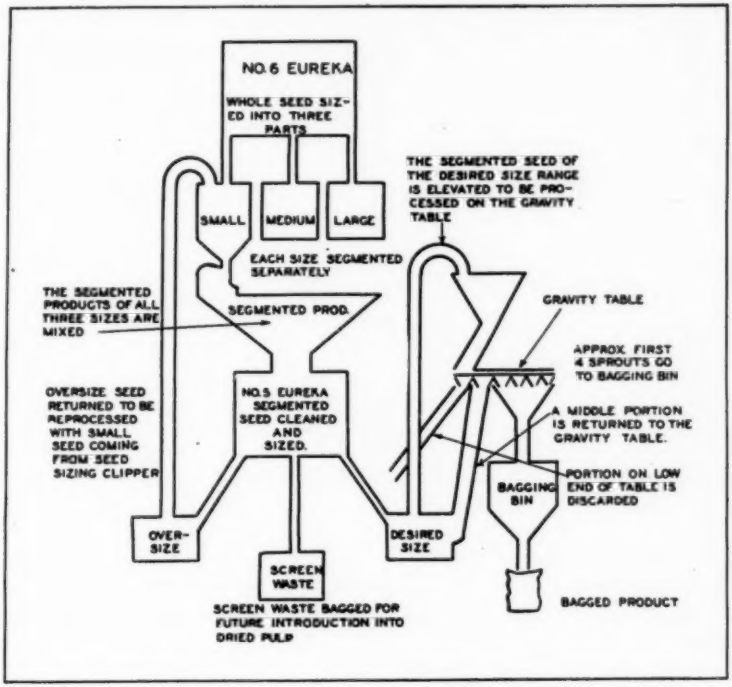
NO. 6 EUREKA
WHOLE SEED SIZED INTO THREE PARTS
SMALL
MEDIUM
LARGE
EACH SIZE SEGMENTED SEPARATELY
THE SEGMENTED SEED OF THE DESIRED SIZE RANGE IS ELEVATED TO BE PROCESSED ON THE GRAVITY TABLE
GRAVITY TABLE
THE SEGMENTED PRODUCTS OF ALL THREE SIZES ARE MIXED
SEGMENTED PROD.
APPROX. FIRST 4 SPROUTS GO TO BAGGING BIN
OVERSIZE SEED RETURNED TO BE REPROCESSED WITH SMALL SEED COMING FROM SEED SIZING CLIPPER
NO. 5 EUREKA SEGMENTED SEED CLEANED AND SIZED.
A MIDDLE PORTION IS RETURNED TO THE GRAVITY TABLE.
PORTION ON LOW END OF TABLE IS DISCARDED
BAGGING BIN
OVER-SIZE
DESIRED SIZE
SCREEN WASTE
SCREEN WASTE BAGGED FOR FUTURE INTRODUCTION INTO DRIED PULP
BAGGED PRODUCT

for final plantings. The percentage of singles may exceed 50 percent but the percentage of doubles and triples would necessitate segmenting of the product.

Table 1.—Whole seed, 16-hour composite. St. George, Utah.

	Pounds per 100 pounds of whole seed	Seedlings per seed ball				Seedlings per 100 seed balls	Seed balls producing 1 or more seedlings
		1	2	3	4 or more		
Whole seed before sizing	100.0	48.5	34.5	10.0	.5	149.5	93.5
After sizing							
Small seed 6/64 to 9.5/64	25.3	48.5	24.5	3.0	1.5	112.5	77.5
Medium seed 9.5/64 to 11/64	58.7	31.0	40.5	18.5	.....	167.5	90.0
Large seed over 11/64	16.0	25.5	35.0	22.0	7.0	189.5	94.5

Table 2.—Results of test to determine size range of small size seed. Variety U. S. 22 and improved; 1944 crop.[1]

Size of screen used	Percent of seed retained on screen	Percent of seed passed through screen	Percent of waste in process
7.75/64	96.8	2.7	.5
8/64	88.3	11.0	.7
8.5/64	89.1	10.4	.5
9/64	79.3	19.8	.9
9.5/64	73.9	25.3	.8

[1]Screens used were ¾-inch slotted. Sizing work was done with a No. 6 Eureka cleaner.

The whole seed grown in southern Utah is normally of large size. This is demonstrated by the results recorded in a test to determine where the break should come in determining the small size seed for segmenting. The results are presented in table 2. No appreciable break in the seed size came until the seed was screened through the 9/64 three-fourths-inch slotted screen. This percentage was not sufficient, however, so we standardized on the 9.5/64. The medium size seed is that passing through the 11/64 and retained on the 9.5/64, and the large sized seed is that retained on the 11/64. All screens used in the sizing operation are three-fourths-inch slotted screens. Each size is segmented separately and the segmented portions of all three sizes are discharged onto a No. 5 Eureka cleaner where the grading of the segmented seed is done. The desired size then goes to the gravity table where the germination is raised to approximately 90 percent; the seed is then bagged. The oversize, or seed that is plus 9/64 in size, is returned and mixed with the smaller size whole seed for an additional segmenting. A flow sheet is shown in table 3.

It is in the segmenting of the seed that the limits of recovery are determined. An inefficient processing of the desired product may reflect itself in recovery losses of 3 to 4 percent on seed introduced, whereas losses in recovery of 10 to 15 percent may be experienced with

Table 3.—Segmenting and processing plan used by Utah-Idaho Sugar Company

Screens Used In Sizing Whole Seed Listed Below	
Lower screen	6/64-inch, ¾-inch slotted
Middle screen	9.5/64-inch, ¾-inch slotted
Top screen	11/64-inch, ¾-inch slotted

Size Range of Seed

Everything passing through the lower screen is discarded as waste.

Small Size—Seed passed through 9.5/64-inch screen and retained on the 6/64-inch screen.

Medium Size—Seed passed through 11/64-inch screen and retained on the 9.5/64-inch screen.

Large Size—Seed retained on the 11/64-inch screen.

inefficient segmenting technique. Processing procedures have to a major degree been mastered to the point that very acceptable recoveries are possible from the segmented seed delivered to the process. This cannot be said of the whole seed being delivered to the segmenting operation. It is this problem of segmenting that has been and is the major interest in our operations. The following remarks relate principally to this subject.

In an attempt to gain a better understanding of the segmenting operation and attain better control, the following procedure was fol-

Table 4.—Screen analysis of samples composited every 2 hours for an 8-hour period at seed plant located at St. George, Utah.

	Wheel No.	Percent seed retained on 9/64-inch round-hole screen	Percent of 7/64 to 9/64 seed recovered	Percent seed through 7/64-inch round-hole screen	Percent germination of seed 7/64 to 9/64
Wheels 1, 2, and 3 segment all small seed and all oversize seed coming from the segmented seed screening operations.	Average No. 1	32.5	36.5	31.0	71
Wheels 1 and 2 handled 75 percent of the oversize; the other 25 percent was handled by wheel 3.	Average No. 2	35.7	31.9	32.4	66
The small seed and oversize were mixed before segmenting.	Average No. 3	26.2	30.2	43.6	69
Average for wheels 1, 2 and 3.		31.47	32.87	35.66	68.67
	Average No. 4	40.3	21.3	38.4	75
	Average No. 5	42.9	20.1	37.0	73
	Average No. 6	40.7	20.9	38.4	76
Average for wheels 4, 5, and 6.		41.30	20.77	37.93	74.67
Wheels 7 and 8 segmented the large size seed.	Average No. 7	48.8	18.0	33.2	73
	Average No 8	52.7	14.7	32.6	62
Average for wheels 7, 8		50.75	16.35	32.90	67.50

lowed for an 8-hour period at our seed plant at St. George, Utah: The segmented product delivered from each segmenting wheel was sampled regularly and the samples from each wheel were composited every 2 hours. A screen and germination analysis was made on each of these composites. Table 4 shows the results of this work.

Average recovery figures for the 8-hour period were as follows: For the three wheels segmenting the small and oversize seed from all three sizes, 32.87 percent 7/64 to 9/64 seed, 31.47 percent oversize, and 35.66 percent waste. For the three wheels segmenting the medium type seed,2 0.77 percent 7/64 to 9/64 seed, 41.30 percent oversize, and 37.93 percent waste. For the two wheels segmenting the large seed, 16.35 percent 7/64 to 9/64 seed, 50.75 percent oversize, and 32.90 percent waste. It was of interest to note that the No. 3 wheel, which was segmenting the least amount of oversize in conjunction with small seed, showed a recovery of 7/64 to 9/64 seed that was 2.67 percent lower than the other two wheels. The initial loss in waste and the low percentage of oversize reflects itself in a lower recovery. This would indicate a definite advantage in adding the oversize to the small seed in this operation. A series of tables (Nos. 5, 6, 7, and 8) are presented in this paper showing calculated recoveries of 7/64 to 9/64 seed, using the recovery figures obtained from the composite samples taken during an 8-hour operation. This method of calculating recoveries has been quite accurate and is presented in detail. This method, as is pointed out in the tables, is simply that of calculating the recovery on the flow of seed through the plant on the basis of a composite sample.

The flow of seed as indicated in table 5 is of great importance in making possible a method of control for better recovery. As indicated in table 1, the initial indication of whole seed would be as follows: For every 100 pounds of seed introduced, 25.3 pounds would go to wheels 1, 2, and 3 as small seed, 58.7 pounds to wheels 4, 5, and 6 as medium size seed, and 16 pounds to wheels 7 and 8 as large seed. As indicated by the recovery figures in table 3, 31.41 percent of the small seed, or 7.96 pounds of the original 25.3 pounds, would return as oversize. A like return of 24.24 pounds of the original medium size seed and 8.43 pounds of the original large seed would occur. The pounds of oversize from the original poundage introduced would again be subject to the same average recovery figures that were used to determine the pounds of return seed in the first case. In calculating recoveries with this method it would appear that from a given 100 pounds of seed introduced, portions thereof would be segmented through the segmenting operation from four to five times before the recovery would be complete. Thus, of the original 100 pounds of whole seed introduced, 25.3 pounds of small seed plus 40.63 pounds of oversize would be segmented by the three wheels segmenting the small

Table 5.—Calculated recovery of 7/64 to 9/64 segmented seed.

	Pounds introduced	Pounds recovered	Pounds waste	Pounds oversize
		Small Seed		
First segmenting	100.00	32.87	35.66	31.47
First return	31.47	10.34	11.23	9.90
Second return	9.90	3.25	3.53	3.12
Third return	3.12	1.03	1.11	.98
Fourth return	.98	.32	.35	.31
Total	100.00	47.81	51.88	
		Medium Seed		
First segmenting	100.00	20.77	37.93	41.30
First return	41.30	13.57	14.73	13.00
Second return	13.00	4.27	4.64	4.09
Third return	4.09	1.34	1.46	1.29
Fourth return	1.29	.42	.46	.41
Total	100.00	40.37	59.22	
		Large Seed		
First segmenting	100.00	16.35	32.90	50.75
First return	50.75	16.68	18.10	15.97
Second return	15.97	5.25	5.70	5.02
Third return	5.02	1.65	1.79	1.58
Fourth return	1.58	.52	.56	.50
Total	100.00	40.45	59.04	

	Size of seed Pounds per 100 pounds whole seed	Percent recovery first segmenting	Pounds recovery first segmenting	Percent recovery on return segmenting	Pounds recovery on return segmenting	Total pounds recovery
Small seed	25.30	32.87	8.32	32.87	3.78	12.10
Medium seed	58.70	20.77	12.19	32.87	11.51	23.70
Large seed	16.00	16.35	2.62	32.87	3.85	6.47
ALL SEED	100.00		23.13		19.14	42.27

and oversize seed. In other words, these three wheels are responsible for the recovery of 7/64 to 9/64 seed from 65.93 pounds of every 100 pounds of whole seed introduced to the process. It is also of interest to note that of the total pounds of recovery (42.27), 23.13 pounds were obtained in the initial segmenting and 19.14 pounds by the subsequent working of the oversize from the initial segmenting. The overage germination of the 42.27 pounds of recovered 7/64 to 9/64 seed was approximately 70 percent. Thus, if no processing loss occurred, approximately 22 percent of the 30 percent of non-variable matter would have to be removed to raise the germination to 90 percent. This would amount to 9.27 pounds on seed introduced but would, of course, not be possible with present processing procedures.

A certain amount of the viable segments are lost in processing and additional losses in poundage are experienced in the scarification that takes place after the seed has been graded to the desired size. Approximately 1 additional pound of viable seed, plus a small loss in dust, would bring the recovery of 90-percent germination 7/64 to 9/64 seed to approximately 31 percent on seed introduced. This was almost identical with the recovery recorded for the day this test was made.

Tables 6, 7, and 8 present calculated recoveries of 7/64 to 9/64 segmented seed from the composite samples of the individual wheels on the small, medium, and large seeds. The samples in each case have been grouped, with the oversize varying about 10 percent in each case. It would appear in the case of the small seed that maximum recoveries are best obtained by recovering as large a percentage of the desired size range as possible in the initial segmenting operation. This has been true in all the work we have done during the past 3 years.

Table 6.—Calculated recovery of 7/64 to 9/64 segmented seed. The 12 composited samples from wheels 1, 2, and 3 have been grouped in three groups with the oversize varying about 10 percent with each group.

	Pounds introduced	Pounds recovered	Pounds waste	Pounds oversize
		Small Seed		
First group				
First segmenting	100.00	28.72	31.00	40.32
First return	40.32	13.25	14.38	12.69
Second return	12.69	4.17	4.53	3.99
Third return	3.99	1.31	1.42	1.26
Fourth return	1.26	.41	.45	.40
Total	100.00	47.84	51.76	
Second group				
First segmenting	100.00	31.05	36.25	32.70
First return	32.70	10.75	11.66	10.29
Second return	10.29	3.38	3.67	3.24
Third return	3.24	1.06	1.16	1.02
Fourth return	1.02	.34	.36	.32
Total	100.00	46.58	53.10	
Third group				
First segmenting	100.00	38.82	39.82	21.35
First return	21.35	7.02	7.61	6.72
Second return	6.72	2.21	2.40	2.11
Third return	2.11	.69	.75	.67
Fourth return	.67	.22	.24	.21
Total	100.00	48.96	50.83	

Table 7.—Calculated recovery of 7/64 to 9/64 segmented seed. The 12 composited samples from wheels 4, 5, and 6 have been grouped in three groups with the percentage oversize varying about 10 percent in each group.

	Pounds introduced	Pounds recovered	Pounds waste	Pounds oversize
		Medium Seed		
First group				
First segmenting	100.00	17.88	31.07	51.05
First return	51.05	16.78	18.20	16.07
Second return	16.07	5.28	5.73	5.06
Third return	5.06	1.66	1.81	1.59
Fourth return	1.59	.52	.57	.50
Total	100.00	42.12	57.38	
Second group				
First segmenting	100.00	21.05	38.08	40.88
First return	40.88	13.44	14.58	12.86
Second return	12.86	4.23	4.58	4.05
Third return	4.05	1.33	1.45	1.27
Fourth return	1.27	.42	.45	.40
Total	100.00	40.47	59.14	
Third group				
First segmenting	100.00	23.32	44.60	32.08
First return	32.08	10.54	11.44	10.10
Second return	10.10	3.32	3.60	3.18
Third return	3.18	1.05	1.13	1.00
Fourth return	1.00	.33	.36	.31
Total	100.00	38.56	61.13	

This is not, however, the case with the medium and large size seed. Maximum recoveries are indicated with the large seeds when smaller percentages of 7/64 to 9/64 seed are recovered on the initial operation with a fairly large amount of oversize. This is very evident in table 7. The indicated final recovery varied from 38.56 to 42.12, as the oversize from the initial operation varied from 32.8 to 51.05. The results presented in this paper and the operation itself are not presented as the ideal operation. Actually, final recoveries were approximately 4 to 5 percent lower than we normally expect. This information is merely presented in an attempt to point out where recoveries can be increased and the method of calculating recoveries at the time that segmenting is being carried on. On table 8 it will be noted in the second group that the oversize averaged 55.94 percent of the seed introduced. In no case should this percentage of oversize exceed 50 percent if maximum recovery is to be expected.

Table 8.—Calculated recovery of 7/64 to 9/64 segmented seed. The 8 composited samples from wheels 7 and 8 have been grouped in two groups with the oversize varying about 13.5 percent with each group.

	Pounds introduced	Pounds recovered	Pounds waste	Pounds oversize
		Large Seed		
First group				
First segmenting	100.00	21.63	36.20	42.17
First return	42.17	13.86	15.04	13.27
Second return	13.27	4.36	4.73	4.18
Third return	4.18	1.37	1.49	1.32
Fourth return	1.32	.43	.47	.42
Total	100.00	41.65	57.93	
Second group				
First segmenting	100.00	13.28	30.78	55.94
First return	55.94	18.39	19.95	17.60
Second return	17.60	5.78	6.28	5.54
Third return	5.54	1.82	1.98	1.74
Fourth return	1.74	.57	.62	.55
Total	100.00	39.84	59.61	

Processing Sugar Beet Seed by Decortication, Burr Reduction, and Segmentation

ROY BAINER and L. D. LEACH[1]

Fifteen to 20 million pounds of sugar beet seed have been used during the past 4 years in the preparation of segmented seed. Most of the machines used for processing the seed were built along the lines of the one used in the early experiments (*1*) (*2*)[2] at the California Agricultural Experiment Station. The rapid adoption of segmented seed was due primarily to the war and its attendant labor shortage, resulting in a demand for processed seed developing at a greater rate than the techniques of processing methods. Actually there was little basic information available for use in the early design of equipment capable of producing seed of optimum quality. This information, in many respects, is still not available even though much experience has been gained from processing large quantities of seed.

Experience in the field and laboratory has revealed certain characteristics of segmented seed behavior that are related to the segmenting process. Among these principally are viability, singleness of germ, and recovery. In addition some seed units produce abnormal seedlings as a result of receiving mechanical injury during the segmenting operation. Low viability in the segmented product is related to the quality of the original whole seed and is due to the inability of separating germ-containing units from non-germinating pieces without sacrificing too much good seed. The production of multiple germ units is probably related to the size, variety, and locality of production of the original seed, the extent of pre-grading, and the setting of the shear bar on the machine. Recovery of segmented seed is influenced by the relation of the germination of the segmented to the original sample and to the nearness of approach to a single germ unit. In fact all three are closely related so that a change in one affects the others. In addition the recovery may be affected by the size, variety, and moisture content of the whole seed as well as by type of seed segmenting equipment used.

Whole sugar beet seed varies from 8/64ths to 18/64ths of an inch in size and may produce from one to as many as five or six seedlings per germinating unit. Because of the extreme range in size it cannot be planted in a uniform manner with present planting equipment. Several planters now available will handle seed in a uniform manner provided the variation in size does not exceed 2 or 3 sixty-fourths of an

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[2]Italic numbers in parentheses refer to literature cited.

inch, depending somewhat upon the shape of the units. The nearer they approach a sphere in shape, the greater can be their variation in size.

Three methods are available for controlling the size range of the seed; namely, grading whole seed, processing whole seed or combinations of the two, and pelleting. Further reference to the latter does not come within the scope of this paper. Whole seed may be graded into three divisions of 3/64 inch size range each. Immediately the difference between the characteristics of each grade presents certain problems. First, the three grades call for three sizes of planter plates for handling the seed; second, the germination will vary considerably between grades; and third, the seedlings produced per viable seed ball will vary for the different grades. Certain grades may be in demand more than others, making it difficult to dispose of all the seed.

Some methods of processing whereby the seed is reduced to a narrow range of size fits in well with a precision planting program. The degree to which it is necessary to carry the processing operation in the production of single germ units has never been fully determined. It would seem evident that seed balls capable of producing more than two seedlings are undesirable if too numerous in the sample. On the other hand, seed that produces one and two seedlings per unit may give a greater factor of safety in obtaining a stand under adverse field conditions.

Plantings made during the past 2 years at Davis have included graded whole seed and large segmented seed. Each had a higher seedling count per viable unit than is commonly regarded as optimum for segmented seed. The plantings were made under a variety of field conditions, giving varying degrees of germination. The plantings were made with planters capable of giving uniform distribution of seeds. Table 1 shows that the percentage of inches having single plants varies inversely with field germination. For example, graded whole seed (12-10)[3] having a potential germination of 1.84 seedlings per viable seed ball gave 45.7 percent singles at a field germination[4] of 70.4 percent, while at 30.1 percent field germination the percentage of inches with single plants amounted to 72.7 percent. Segmented seed (10-8) having a potential germination of 1.38 seedlings per seed ball produced singles on 82.8 percent and 70.1 percent of the beet-containing inches at field germinations of 30.5 percent and 53.9 percent respectively. From these comparisons it appears that further investi-

[3](12-10) indicates size of seed. In this case the seed passed through a 12/64 inch screen and over a 10/64 inch screen.

[4]Field germination refers to the emergence of seedlings in the field as a percentage of the total seedlings per 100 seed units as shown by laboratory or greenhouse germination trials.

Table 1.—Comparison between field germination and percentage of inches with singles for graded whole seed and large segmented seed.

Seed	Size	Germination Percentage	Seedlings per viable unit	Pounds per acre	Field germination percentage	Percent inches with singles
Whole	12-10	96.0	1.84	4.6	70.4	45.7
Whole	12-10	96.0	1.84	4.4	44.5	57.5
Whole	12.10	96.0	1.84	4.0	30.1	72.7
Segmented	10.8	92.6	1.38	3.4	53.9	70.1
Segmented	10.8	92.6	1.38	3.6	30.5	82.8

gations are justified in processing seed in such a way that it can be planted in a precise manner, at the same time maintaining or improving germination as related to the original seed and eliminating through reduction those seeds containing more than one or two germs.

A machine was built for removing the cork, leaving the seed as smooth as possible and at the same time rubbing the larger seeds hard enough to empty some of the locules of germs, thereby reducing the number of multiple seed units. The device for decorticating the seed consists of a silicon carbide stone (Norton 37C24QV) 10 inches in diameter mounted on the upper end of a vertical shaft (figures 1 and 2). The shaft is mounted in a frame with suitable bearings for taking both radial and thrust loads. Power to the shaft is furnished through a single B section V belt from a 2 h.p. electric motor. Pressure pads, consisting of ½ inch of either rubber or neoprene vulcanized to a round plate 10 inches in diameter with a 5-inch round hole at the center, were used for holding the seed against the revolving stone. The rubber pad was cured to give a durometer reading of 65,

Figure 1.—Machine used for decortication and burr reduction.

Figure 2.—Decortication is accomplished through the use of a pressure pad for holding seed against a revolving grinding wheel.

while the neoprene gave a reading of 45. The pressure pads were molded with a taper of ⅛ inch per 2½ inches, converging toward the outside to facilitate feeding. This taper was lost during the processing of 200 to 300 pounds of seed because of greater wear near the outer edges where the pressure was the greatest. The pressure pads are attached to an adjustable plate immediately above the stone. Clearances of 0.125 to 0.150 inches are maintained, depending upon the size of the seed. The stone and pressure pad are enclosed in a steel case with a hoppered bottom. A suction fan connected to the discharge at the bottom of the hopper removes fine dust resulting from the operation. A large hopper above the unit feeds the whole seed to the center of the wheel. The stone is operated at 775 r.p.m. which gives a peripheral speed of approximately 2,000 feet per minute. Centrifugal force moves the seed from the center to the periphery of the stone.

During preliminary trials with the machine equipped with the neoprene pad, the whole seed was pregraded over a 12/64 or 13/64 inch screen to divide the lot into approximately two equal parts. The larger size was then run through the machine twice, once at a clearance between the pressure pad and stone of 0.175 inch and again at 0.150 inch. The small seed was run first at 0.150 inch and finished at 0.125 inch. Capacities (150 to 200 pounds per hour) were greater if the seed was decorticated at two settings, each removing part of the cork, than if an attempt was made to remove it all at one time. Following the decoritcation the seed was aspirated and graded into two sizes: 11-9 and 9-7. Later, when the rubber pressure pad was available, sack run seed was run at 0.150 inch with the rubber pad and finished at 0.125 inch clearance with the neoprene pad. After aspiration, the seed was graded 10-7.

Whole seed weighs 18 to 22 pounds per bushel. After decorticating, cleaning and grading, it weighs 35 to 40 pounds per bushel. Inasmuch as 40 to 50 percent of the original weight is lost during the process and its unit weight is doubled, the volume occupied by decorticated seed amounts to less than ⅓ that occupied by the whole seed from which it was produced.

The early seed processing studies were concentrated on one lot of seed, (U. S. 33L343) in order to make accurate comparisons of the results obtained from time to time. Before the work was started a screen analysis was made and germination tests were run on the seed. Results of this analysis are shown in table 2. Such a study is enlightening and at the same time serves as a guide to subsequent grading and processing studies.

Preliminary results showing decortication trials on several lots of seed are shown in table 3. The U. S. improved 22, used in the trial, germinated 85.25 percent in its original form, producing 1.95 seedlings per viable seed unit. A pound of the whole seed contained 25,235 units, and it weighed 18 pounds per bushel. Following decortication and aspiration the seed was graded 10-7. The germination based on normal seedlings amounted to 94.0 percent. In addition there was 1.5 percent producing abnormal seedlings as a result of the processing operation. A pound of the decorticated seed contained 34,692 units and the bushel weight amounted to 38 pounds. This seed produced 1.78 seedlings per viable seed unit. The recovery based on weight of the original sample amounted to 50.7 percent. When expressed on the basis of seed units the recovery was 69.7 percent, and when expressed in viable seed units it amounted to 76.8 percent.

The germination of the decorticated seed was equal to or above that of the original whole seed sample for all varieties shown in table 3. Outstanding results were obtained from one sample of U. S. 15 where the original germination was only 59.5 percent. Decortication of this seed resulted in a recovery of 33.0 percent by weight and 55.6 percent by viable seed units, raising the germination to 92.0 percent. On the other hand another lot of U. S. 15 (not shown in the table), having a germination of 38.0 percent was not improved materially through decortication. The reasons for the difference in performance of these two seed lots have not been fully determined.

Following decortication, aspiration, and grading (9-7) a lot of seed germinating 89.25 percent was classified on a gravity table. The seed from each of the first three spouts germinated 97.25 percent. The combined recovery for these three spouts, on the basis of the original sample, was 42.2 percent. The seed from spouts 4 and 5 showed a germination of 94.5 percent and represented 47.2 percent of the total sample, while the seed from spout 6, representing 10.6 percent of the total, germinated 69.0 percent. When the increment from spout

Table 2.—Screen analysis and laboratory germination of sugar beet seed. Variety U. S. 33, lot 343, whole seed.

Seed size	Recovery by weight percentage	Laboratory germination						Seedlings per 100 seed units	Seedlings per viable seed unit	Seed units per pound
		Percent	Singles	Doubles	Triples	Quads	Quints			
Composite	100.00	81.50	34.00	40.00	6.50	1.00	0	137.50	1.69	29,990
18/17	0.51	97.50	5.00	27.50	38.50	24.75	1.75	283.25	2.91	9,460
17/16	0.51	96.75	9.00	31.00	36.75	19.75	.25	261.50	2.70	11,350
16/15	8.18	95.50	20.50	41.50	28.00	5.50	0	209.50	2.19	14,190
15/14	6.15	92.00	23.75	50.00	16.75	1.50	0	180.00	1.96	17,564
14/13	15.20	87.00	25.00	47.50	14.50	0	0	163.50	1.89	21,300
13/12	11.13	78.50	34.25	39.25	4.25	.75	0	128.50	1.64	22,620
12/11	20.85	76.00	33.75	37.25	4.75	.25	0	123.50	1.62	27,320
11/10	20.85	68.75	38.00	29.25	1.50	0	0	101.00	1.47	35,800
10/9	9.95	64.75	39.75	24.75	0.25	0	0	90.00	1.39	46,400
9/8	4.88	46.50	33.50	12.75	0.25	0	0	59.75	1.28	61,500
8/7	1.03	46.75	37.00	9.75	0	0	0	56.50	1.21	67,450
7/6	0.34	34.25	27.25	7.00	0	0	0	41.25	1.20	92,102
6/PAN	0.34									

Table 3.—Sugar beet seed processed by decortication, burr reduction, and segmentation.

Process	Size	Germination percent		Seedlings per viable unit	Seeds per pound	Recovery percent			Pounds per bushel
		Normal	Abnormal			Weight	Number	Viable units	
				U. S. Improved 22					
Original	Sack run	85.25	....	1.95	25,235	100.0	100.0	100.0	18.0
Decortication	10-7	94.0	1.5	1.78	34,692	50.7	69.7	76.8	38.0
Burr reduction	11-8	94.75	1.25	1.70	33,914	50.9	68.4	75.8	27.0
				215 x 216					
Original	Sack run	94.0	0.25	1.86	30,597	100.0	100.0	100.0	20.0
Decortication	10-7	93.5	0.75	1.68	39,443	53.6	69.2	68.8	39.0
Burr reduction	11-8	95.0	2.25	1.89	30,700	68.0	68.4	69.2	26.0
				Mid-west 4					
Original	Sack run	91.0	0.25	1.91	28,394	100.0	100.0	100.0	21.5
Decortication	10-7	97.25	0.25	1.87	33,538	56.6	66.9	71.5	36.0
Burr reduction	11-8	94.75	1.0	1.83	31,229	75.0	82.6	80.0	27.0
				G. W. 267					
Original	Sack run	78.50	....	1.71	27,574	100.0	100.0	100.0	18.5
Decortication	10-7	89.75	1.25	1.51	34,289	43.8	54.5	63.2	35.0
Burr reduction	11-8	82.50	1.0	1.65	31,337	64.2	73.0	76.8	24.5
				U. S. 15					
Original	Sack run	85.5	0.5	1.83	34,892	100.0	100.0	100.0	20.5
Burr reduction	11-8	91.0	1.0	1.76	37,565	71.6	77.0	82.0	26.5
				U. S. 15					
Original	Sack run	59.50	0.25	1.53	36,071	100.0	100.0	100.0	21.0
Decortication	10-7	92.0	1.0	1.51	39,358	33.0	36.0	55.6	39.0
				A. C. 3					
Original	Sack run	80.25	0.25	2.08	27,202	100.0	100.0	100.0	19.5
Decortication	10-7	92.0	1.0	1.80	36,581	44.3	59.3	68.1	36.0
				U. S. 33					
Original	Sack run	84.25	1.75	1.69	28,040	100.0	100.0	100.0	20.0
Decortication	10-7	91.0	2.25	1.51	35,858	51.8	66.3	71.6	34.0
Burr reduction	11-8	89.5	2.75	1.59	32,030	68.0	77.7	82.6	26.0
Segmentation	9-7	74.75	10.0	1.13	49,459	32.0	57.7	50.6	24.5
Combined burr and decortication	9-7	83.75	4.5	1.46	39,876	48.8	69.4	69.0	35.0

6 was reduced to 7.6 percent of the total by aspiration, the germination amounted to 81.25 percent.

In some localities there is a trend toward supplying graded whole seed. The sizes usually furnished are either 12-9 or 11-8. This leaves approximately one-half of the seed to be reduced mechanically and blended back in order to keep within the selected size range. If the small graded seed is used alone there is some likelihood of the germination being lower than for the original sample. By referring to table 2 and considering the 11-8 size of this particular lot of seed it will be found that this increment contains 35.68 percent of the original sample by weight, 53.6 percent by number, and 42.3 percent by viable seed units. This size shows a germination of 64.4 percent and produces 1.49 seedlings per viable seed unit, as compared with a germination and seedling count of 81.5 percent and 1.69 respectively for the original sample. By selecting the 12-9 size the germination would be raised to better than 70 percent. Other lots of seed would show different results; therefore these figures pertain only to this specific sample.

Because of the trend towards planting graded whole seed, a machine was built to reduce the oversize seed to the size of the graded product. The machine built for decorticating seed was modified for this work, (fig. 3). A Radiac stone (9716NV2) was substituted for the Norton stone. The grit size in the Radiac stone is larger and arranged to give a lower density. The bond strength of the stone was too weak for this particular job, resulting in excessive pitting while processing only 1,000 pounds of seed. Further work with other stones is contemplated. The pressure pad was replaced by a Letz feed grinder burr plate (No. AA230). A minimum clearance of 0.125 inch is used between the burr plate and stone. Whole seed is fed into the machine in the same way as described for

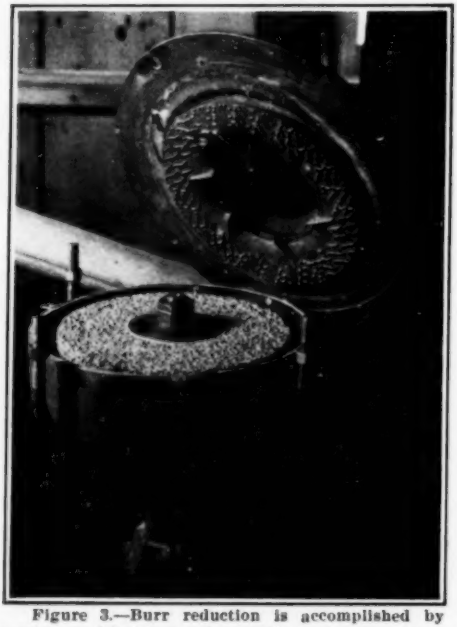

Figure 3.—Burr reduction is accomplished by passing seed between a burr-plate and coarse stone.

the decorticator. The capacity of the unit varies from 600 to 800 pounds per hour. Following the burr reduction the seed is aspirated and graded 11-8. Usually 5 to 10 percent of the seed will not pass the larger screen on the first grading and must be re-run through the machine for further reduction.

Seed processed by burr reduction has the appearance of whole seed except for size. The units are more spherical in shape than segmented seed. The results of the runs employing burr reduction are shown in table 3. As an example, U. S. Improved 22 shows that the results were almost identical with those obtained from decortication, except that the seedlings produced per viable seed unit and the bushel weight were lower. In other lots of seed processed the seedling count per viable seed unit was slightly higher than for decorticated seed.

Segmented seed was produced from U. S. 33 for use in comparative field trials. Segmented seed producing, as nearly as possible, one seedling per viable seed unit was desired. Therefore, the process was carried out to produce 9-7 seed. The segmented seed showed a total germination comparable with the original seed, but 10 percent of the seeds produced abnormal plants to give a normal germination of 74.75 percent as compared to 84.25 percent for the original (table 3). Recoveries of 32.0 percent by weight, 57.7 percent by number, and 50.6 percent by viable seed units were obtained. Segmenting to this size was too drastic for this particular lot of seed.

One size of decorticated seed (9-7) was produced by first reducing all whole seed over 12/64ths in size by burr reduction, then running it through the decorticator with the whole seed that passed the 12 screen. This combination on U. S. 33 (table 3) produced seed in which the original germination was practically maintained. The seedlings per viable seed unit were reduced from 1.87 to 1.46 as a result of the process. The recovery amounted to 48.8 percent by weight and 69.0 percent on the basis of viable seed units. The next step in this combination is to produce 10-7 or 11-8 seed in an endeavor to raise the percentage of recovery.

Decorticated seed averages between 33,000 and 40,000 seed units per pound for the 10-7 size as compared to approximately 50,000 or more units for segmented seed of the 9-7 size. A pound of seed reduced by burr reduction and graded 11-8 contains 30,000 to 38,000 seed units, as compared to 25,000 to 35,000 seed units per pound of whole seed. Seed produced by decortication or burr reduction has characteristics superior to segmented seed in every respect except one, namely, singleness of germ. Seed processed by combining burr reduction and decortication approached the upper limit found in segmented seed produced by some of the western sugar companies in re-

gard to singleness of germ units.

The speed of operation of the processing equipment influences to a considerable degree the number of abnormal seedlings produced. Seeds upon leaving the wheel are thrown against the wall of the steel case surrounding the unit. One lot, decorticated when the stone was operating at 3,500 feet per minute (peripheral speed), produced a high percentage of abnormal germination. A large part of the damage consisted of broken roots. The same lot when processed at a speed of 2,000 feet per minute produced 7.5 percent abnormal seedlings. The percentage of abnormal seedlings was reduced to 2.0 percent by padding the inside of the steel case with a piece of rubber floor mat. A further reduction in abnormal seedlings was obtained through the use of a half-inch layer of sponge rubber. Additional tests are needed to determine the relation of the speed of operation, and possibilities of cushioning the impact, on the production of abnormal seedlings.

A planter development program has been carried along simultaneously with the seed processing investigations. In order to get a true picture of the behavior of the seeds processed in different ways, it is necessary to plant them one at a time in a uniform manner and spaced far enough apart to determine the seedlings produced by each seed unit. A John Deere horizontal plate planter with certain modifications was used. Greased board tests were used during the development period to check the distribution of seed as the improvements were made. Plates were made to fit the seed processed in different ways (table 4). Smooth tubes (chrome-molly seamless steel tubing ½-inch O. D.) described by Bainer (*3*) were attached to the false plate. The cut-off was changed in shape to conform more to that of a plow. The spring pressure on the cut-off and knock-out wheel was doubled to prevent seeds from lifting the cut-off up and lodging under it. This made it necessary to increase the pressure against the bottom of the false ring by a similar amount. The relief in the false ring, immediately below the knock-out wheel, was milled to the radius of the wheel plus the thickness of the plate. The teeth on the knock-out wheel were dressed down slightly to give freer entrance and exit to the cell.

The performance of the planter for the different types of seed used is shown in table 4. At the theoretical spacing of 2.92 inches the data from a perfect planter would show all of the seeds in column marked "1" under seeds per inch, and 92 percent of the figures under inch spaces without seeds would be in the 2-inch column and 8 percent would be in the 1-inch column. An arrangement of data as just described would give a dispersion coeficient of "0". The method used for determining the dispersion coeficient was developed by Brooks and Baker (*4*).

Table 4.—Greased board tests of horizontal plate planter used for segmented, decorticated, and burr-reduced seed. Planter equipped with14-inch length of ½-inch O. D. crome-molly tube. Theoretical spacing 2.92 inches. Board speed 2¼ m.p.h. Total of four 8-foot boards.

	Seeds per inch			Inch spaces without seeds							Dispersion coefficient
	3	2	1	0	1	2	3	4	5	6	
Decorticated (11-9) through 12/64" cell. Plate thickness 0.137 inch			132	1	27	93	13				0.026
Decorticated (9-7) through 9.5/64 cell. Plate thickness 0.110 inch		2	133	2	38	77	16	1	1		0.100
Segmented (9-7) through 9.5/64 cell. Plate thickness 0.110 inch		13	125	8	46	56	28	1			0.323
Burred (11-9) through 12/64" cell. Plate thickness 0.137 inch		3	127	11	28	60	23	4	2	1	0.225
Burred (11-8) through 12/64" cell. Plate thickness 0.137 inch		6	129	5	30	82	17	1			0.184

Seed processed by burr reduction and graded 11-8 gave slightly better planter performance than that graded 11-9. This was probably due to slightly better cell fill. Better performance was shown for the decorticated seed than for the seed processed in other ways. This was due to their smooth exterior and uniform shape. The test showed no inches with doubles for the 11-9 seed and only 2 for the 9-7 seed in 32 feet of greased board.

Recent modifications of the International Harvester Company planter, along the same lines as described for the Deere unit, gave similar results. Both the Lindeman-Cobbley and Rassmann vertical plate planters are capable of similar performance.

Following the laboratory tests two units of the John Deere planter were mounted on a sled for planting on beds. The units were geared to be driven by the power take off of the tractor. This type of drive eliminated slippage as far as possible. A revolution counter on the final drive gave the turns of the plate so that the opportunities for seeds to be dropped could be calculated for a known distance. The machine was set for as near the spacing used on the greased boards as possible. The discrepancy was 0.1 inch between seeds (theoretical). A field speed of 2¼ m.p.h., the same as for the greased board, was used.

One field planting was put in before the winter rains set in. It was made with the planter set to sow 4.27 (theoretical) seeds per foot.

Three additional plantings were put in at a slightly higher seeding rate during March 1946. A tabulation of the stand counts is given in table 5.

The November planting (table 5) resulted in field germinations of 70.4, 88.2, and 69.0 percent for segmented, decorticated, and burred seed, respectively. Under these conditions segmented seed with 87 percent singles (greenhouse germination) produced a stand with 85.9 percent of its inches containing singles in the field. Decorticated seed having 42 percent of its seeds containing single germs produced a stand with 54.8 percent inches with singles, while the burr-reduced seed with 36 percent of its seeds containing single germs produced a stand with 53 percent of its inches containing singles.

With 4.25 seeds planted per foot there were no skips exceeding 10 inches for either the burr reduced or decorticated seed. On the other hand at a seeding rate of 5.07 seeds per foot the segmented seed planting showed skips of 13, 16, 17, 21, and 42 inches in the twenty-four 100-inch counts.

When the stand was recalculated on the basis of 100 seed units planted (table 5), the decorticated seed produced 47 inches with singles as compared to 50.2 for the segmented seed. In addition there were 37 inches with doubles as compared to 9 for the segmented planting.

Plantings made under less favorable germinating conditions gave an entirely different result. The percentage of field germination for the March 15 planting (table 5) amounted to 20.4, 44.8, and 40.7 percent for segmented, decorticated, and burred seed, respectively, while the percentage of inches with singles amounted to 90.0, 75.1, and 70.2 percent for the three types of seed. When the data was recalculated on the basis of 100 seed units planted there were over twice as many inches with singles for either the decorticated or burred as compared with segmented seed. Decorticated and burred seed gave 35.62 and 34.82 inches with singles for each 100 seeds planted, as compared with 16.4 inches with singles from 100 units of segmented seed.

Plantings of decorticated and burred seed were put in with a distributed hill plate. The plate was designed and operated to place three seeds, 1.4 inches apart, in hills on approximately 10-inch centers. Decorticated seed at 2.43 seeds per hill produced 256 plants in 105 beet-containing hills per 100 feet with 75.8 percent of the inches, within the hills containing beets, with singles. Burred seed at 2.62 seeds per hill produced 229 plants in 102 beet containing hills per 100 feet with singles in 67.8 percent of the inches. This method of planting resulted in the plants emerging as if blocked and required the removal of one or two plants per hill to leave a satisfactory stand of beets.

An 80-acre field near Davis was planted with decorticated seed

Table 5.—Field plantings using segmented, decorticated, and burr-reduced seed. Counts made 1 month following planting. Four replications each planting. Average of twenty-four 100-inch counts each replication. U. S. 33, Lot 343, used in all plantings.

Seed	Size	Pounds per acre	Seeds per foot	S	D	T	Q	Total inches	Total plants	Percentage inch singles	Percentage field germination
					November 14, 1945, planting						
Segmented	9-7	2.62	5.07	21.1	3.8	0.25		25.2	29.5	83.9	70.4
Decorticated	9-7	3.27	4.24	16.6	13.3	0.62	0.06	30.6	45.4	54.8	88.2
Burred	11-9	3.72	4.25	13.7	11.2	0.8	0.15	25.8	38.9	53.0	69.0
					Emergence based on 100 seed units planted						
Segmented	9-7			50.2	9.0	0.59		59.8	69.9	83.9	70.4
Decorticated	9-7			47.0	37.7	1.76	0.17	86.6	118.7	54.8	88.2
Burred	11-9			38.7	31.6	2.26	0.42	73.1	109.8	53.0	69.0
					March 6, 1946, planting						
Segmented	9-7	4.02	7.60	13.95	2.66	0.41	0.08	17.3	20.74	81.6	33.2
Decorticated	9-7	3.72	4.92	13.15	6.54	0.29	.. ....	20.0	27.10	65.9	48.4
Burred	11-9	4.30	4.87	14.36	6.96	0.66	0.16	22.3	30.90	64.9	47.8
					Emergence based on 100 seed units planted						
Segmented	9-7			22.1	4.2	0.63	0.12	27.05	32.87	81.6	33.2
Decorticated	9-7			32.2	15.95	0.71	.. ....	48.86	66.23	65.9	48.4
Burred	11-9			35.4	17.16	1.63	0.39	54.58	76.17	64.9	47.8
					March 15, 1946, Planting						
Segmented	9-7	4.17	7.90	10.78	1.20	.. ....	.. ....	12.03	13.18	90.0	20.4
Decorticated	9-7	4.02	5.30	15.74	5.21	0.16	.. ....	21.12	26.64	75.1	44.8
Burred	11-9	4.17	4.72	13.70	5.96	.. ....	0.04	19.70	25.78	70.2	40.7
					Emergence based on 100 seed units planted						
Segmented	9-7			16.4	1.82	.. ....	.. ....	18.22	20.04	90.0	20.4
Decorticated	9-7			35.62	11.80	0.36	.. ....	47.42	60.30	75.1	44.8
Burred	11-9			34.82	14.80	.. ....	0.10	49.62	64.82	70.2	40.7
					March 25, 1946, planting						
Segmented	9-7	4.12	7.79	8.17	1.58	0 08	.. ....	9.83	11.52	83.2	19.0
Decorticated	9-7	3.90	5.16	10.70	4.58	0.16	.. ....	15.44	20.34	69.2	35.0
Burred	11-9	4.20	4.76	9.75	3.04	0.16	.. ....	12.95	16.21	75.3	26.8
					Emergence based on 100 seed units planted						
Segmented	9-7			12.55	2.43	0.12	.. ....	15.1	17.77	83.2	19.0
Decorticated	9-7			24.8	10.67	0.37	.. ....	35.84	47.25	69.2	35.0
Burred	11-9			24.6	7.67	0.41	.. ....	32.67	41.14	75.3	26.8

at 3.03 pounds per acre (3.82 seeds per foot). The seed used was graded 10-7 and was classified over a gravity table following the processing operation. The laboratory germination on this lot of seed was 95.6 percent and it produced 1.75 seedlings per viable seed ball. The bushel weight was 39 pounds. The planting was done on beds with the new John Deere No. 66 smooth tube planter operating at 3 m.p.h. Depth of planting was 1½ inches. Following planting, the field was irrigated to insure germination moisture. Under an average field emergence of 49.4 percent, stand counts showed 17.85 inches per 100 inches with a total of 24.75 plants. Of the 17.85 inches with plants, 11.42 inches, or 64 percent contained singles, 6.06 inches had doubles, and 0.4 inches contained triples. Under the field germination (49.4 percent) of this trial, seed showing approximately 25 percent singles in a laboratory germination produced a stand in which 64 percent of the inches contained single beets. No doubt some of the seedlings growing in adjacent inches came from the same seed ball; nevertheless they appeared as separate plants. Thinning of this field was combined with the first hoeing for weeds. The resulting stand amounted to 119 beets per 100 feet.

Field plantings made under a wide range of germinating conditions will no doubt furnish further important information on this subject.

Summary

1. Fifteen to 20 million pounds of sugar beet seed have been used during the past 4 years in the preparation of segmented seed.

2. The demand for processed seed has developed at a greater rate than the techniques of processing methods.

3. Experience in the laboratory and field has revealed certain characteristics of segmented seed behavior that are related to the segmenting process. Principal among these are viability, singleness of germ, and recovery.

4. Size range of either whole or processed seed must be controlled to 2/64 or 3/64 if used with good results in precision planters.

5. Beet seed may be reduced to a narrow size range by grading, segmentation, decortication, or burr reduction.

6. Seed processed by decortication or burr reduction gives germinations comparable with the initial whole seed.

7. Decorticated seed weighs 35 to 40 pounds per bushel as compared with approximately 20 pound per bushel for whole seed. It

occupies about ⅓ of the volume of the whole seed from which it is produced.

8. The recovery of decorticated seed varied from 55.6 percent to 76.8 percent on the basis of viable seed units in the original seed. Seed reduced by burr reduction showed a recovery of 69.2 percent to 86.0 percent on the basis of viable units. Segmented, reduced to give 87 percent single germ units, showed a recovery of 50.6 percent on the basis of viable units.

9. Seed processed by combining burr reduction and decortication was reduced to 9-7 size with a germination comparable with the original seed. The seedlings produced per viable unit amounted to 1.46 as compared to 1.87 for the original seed. The recovery was 69.0 percent on the basis of viable seed units.

10. Horizontal plate planters equipped with proper plates and small smooth tubes in place of the usual spiral ribbon tubes are capable of doing precision planting with graded whole or processed seed.

11. Segmented, decorticated, and burr-reduced seed produced stands with 83.9, 54.8, and 53.0 percent of the inches with single plants when their respective field germinations were 70.4, 88.2, and 69.0 percent. Under field germinations of 20.4, 44.8, and 40.7 percent, respectively, segmented, decorticated, and burr-reduced seed produced stands with 90.0, 75.1, and 70.2 percent of the inches with single plants.

12. Stand counts made on the basis of 100 seed units planted in replicated plantings of segmented, decorticated, and burr-reduced seed showed 16.4, 35.6, and 34.8 inches containing single plants under field germinations of 20.4, 44.8, and 40.7 percent, respectively.

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GENERAL MACHINERY SYMPOSIUM

The Need For Mechanization and a Brief Review of Accomplishments

P. B. SMITH[1]

Ordinarily it is considered that sugar beets require slightly less than 100 man-hours per acre during the season. About one-half of this requirement is hand labor to thin, weed, and top the beets. Machinery and chemistry can well eliminate a large share of the hand labor required as well as the need for extra weeding cultivations. By eliminating hand loading and harvesting, a material amount of manpower may also be saved. According to time studies, the raising of an acre of corn requires 34 man-hours. It is quite possible that sugar beets, if completely mechanized, will require but little more. When this is achieved no other crop, including wheat, will have as much food energy produced per man hour of effort. The elimination of "stoop" labor is at the present time of the utmost importance to the industry. Not only has it been the object of much political criticism but also it has cost processors large sums of money and resulted in considerable grower dissatisfaction.

The domestic beet industry is quite varied over the 18 states in which sugar beets are grown. The average size of beet contracts varies from 6½ acres in Wisconsin to 87 acres in Southern California. Naturally it is easier to mechanize where the farm size units permit adequate power equipment. There is a general lack of standardized practices in the various sugar beet areas, not only in the width of rows but in the matters of planting, irrigating, and harvesting. Row widths vary from 18 inches in Minnesota to as much as 42 inches in California. Needs for irrigation furrows affect mechanical operations. Lack of smooth, level fields greatly affects mechanical thinning in non-irrigated sections. All this lack of universal methods makes for rather complicated summer labor elimination as well as harvest labor elimination.

Considerable progress has already been made in recent years in reducing hand labor requirements by introduction of segmented seed, seed treatments, mechanical blocking, field beet loaders, and complete harvesters. The industry needs a single-germ beet seed. Present indications are that even this problem seems to have some assurance of being whipped by plant breeders. In the meantime, before the single-germ seed might be available, the industry needs improved seed processing to eliminate damage to germs and to standardize quality as well as size of seed. It is very difficult for implement manufacturers to

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understand the variance in opinion in the industry as to the size of segmented seed to be issued to growers. The University of California has been doing some excellent work along seed processing development.

Stress is going to have to be put on precision beet planters and preparation of seed beds if we are to eliminate thinning labor. In order to make the seed come through the ground with assurance of growing healthily we need further studies with fungicides and fertilizers. In many sections, because of crust problems, work needs to be done on chemicals such as gypsum, lime, and others to make the ground more friable, thereby eliminating crust and associated seedling troubles that are caused by it. In order to plant light rates of single-germ seed or uniform double-germ seed, a drill which does not damage the seed and which can be counted on to distribute the seed fairly accurately is badly needed. In some areas stress should be put on drills that prepare the soil as well as kill weeds in the drilling operation. Studies should continue also on improved press wheel design and furrow openers. It seems quite possible that planting rates of two seeds per foot of row may be achieved in the future when better emergences are secured from high germinating seed that will have increased chances of growing because of previous seed treatments. The selective elimination of weeds by chemical means seems to be on the way to solution. When this is achieved agronomic practices are going to have to step up in order to keep pace with the mechanical phases of producing beets. The use of commercial fertilizers is going to become more and more popular and the use of micro-organisms in the soil to improve its fertility as well as its condition will naturally come along with demands for increased production.

The development of planting equipment and subsequent methods to eliminate hand thinning is further from ultimate solution than are the mechanical harvesters. The use of mechanical blockers, such as the "Dixie", "Soucci", "Blackwelder" and other down-the-row blockers, as well as cross blockers, is dependent upon the uniformity of the spacing of the plants down the row. Single plants are important up to a reasonable degree in order that the blocking will not leave bunches of plants which would interfere with yields. When farmers get accustomed to mechanical blockers there is very little question that yields can be increased. The final blocked stand depends in a large measure upon the successful emergence of uniformly distributed seed. This has not yet been too well accomplished with present equipment. Part of this failure probably is due to too rapid planting with present drills, to lack of seed bed preparation, and to weeds, crust, and other factors. Timeliness is very important in all mechanical operations.

There are many harvesters, both experimental and in production, that give promise of satisfying the need for harvesting the crop. A

survey of the industry indicates that the harvesters wanted by farmers should be capable of handling clods on about 60 percent of the total acreage in the country. Opinion of farmers is about equally divided between a machine that might in a single operation handle both tops and roots and a machine which might harvest the tops separately from the roots—a two-unit machine. This survey indicated that the ultimate harvest equipment should satisfactorily salvage the tops on 86 percent of the land growing beets. This fact indicates quite clearly that eventually the beet industry will be responsible for much more livestock feeding than it is today. The importance of properly taking care of the tops should be more seriously considered in harvest operations.

About one-tenth of the acreage planted to beets in 1945 was harvested mechanically. It would appear that in 1946 perhaps one-fourth might be mechanically harvested if sufficient machines can be produced. The average beet contract in the United States is 20 acres and on about 34,000 farms the average is less than that; it would seem that a one-row harvest operation would be adequate on these farms. There are about 15,000 farms that usually grow in excess of 20 acres, with 2,200 growing more than 60 acres. The latter probably will be adapted for two row or larger machines. The topping accomplished by most of the harvesters today is superior to that done by hand workers. This part of the operation is pretty well solved but much work needs to be done to handle machines in muddy ground, in rocky fields, and under extremely dry conditions before it can be said that a universally acceptable machine is produced. It is very doubtful that a single type of harvester can be devised that will adequately harvest beets in all areas of the United States because of the peculiar problems in each area. In the next few years great improvements will be made on present equipment in improving the quality of work, particularly in caring for the tops properly and in the elimination of trash, clods, rocks, and other things that interfere with the operation of sugar factories and in the storage of beets. With the mechanical developments now under way, combined with the work being done by chemists, electrical engineers, and others, it would seem that the elimination of much of our hand labor will have been accomplished within the next 5 years.

The Beet Sugar Development Foundation is concentrating its program on the development of devices to eliminate the need for hand labor. Specifically this will be divided into four parts:

(1) A thorough study of drills and seed processing in a nationwide series of tests. A great many inventors have designed planters which will be tested at Fort Collins.

(2) A thorough study at a great many locations of mechanical

thinning of beets as well as a further investigation of wide and narrow row possibilities.

(3) A thorough study of harvesters next fall in various parts of the country. About 28 different kinds of harvesters have been investigated. Assistance is being given to improve production models as well as experimental models of these machines.

(4) Extension facilities for promoting the more widely adaptable practices for elimination of labor. These will be prepared and loaned to sugar companies.

Through the cooperation of all research and other agencies the Foundation hopes in this year to make a great stride for increasing the mechanization of the crop of 1947 when materials and machinery will be probably available to fill the demand by sugar beet farmers more adequately.

What We Need In a Beet Drill

RALPH L. PARTRIDGE[1]

We are all today facing the necessity of changing as rapidly as possible from our present hand labor methods of growing the sugar beet crop to the mechanization of the crop. It is apparent that it will be necessary to handle part of the crop mechanically this year if we are going to get and successfully handle the acreage that it is now indicated the growers desire to grow.

In order to mechanize the thinning successfully, it is necessary that the proper stand of beets be secured. This means that as far as the Great Western districts are concerned we must come to a lower seeding rate per acre, using as far as possible drills that will give uniform spacing of the seed in the row.

Considerable work has been done and progress has been made in solving this problem. Last winter a remodeling of some of the John Deere 55's was done, and one of these remodeled drills was furnished to each factory district of the Great Western Sugar Company. In all cases excellent results were secured. Stands obtained from plantings with this remodeled drill are easily handled by either a hoe alone, by blocking, or by a combination of both. Any of these methods eliminates finger work and saves from 50 to 75 percent of the labor necessary to handle spring and summer work on the crop.

Changes made in remodeling this drill were as follows: Cans were lowered and set immediately on top of the disk furrow openers. Seed was discharged from the cans into a half-inch diameter, stainless-steel tube. The tube ran down through the disk furrow opener with a slight curve in the tube, discharging the seed almost immediately below the hub of the disk. This discharged the seed at the proper point so that the seed was not caught between the disk and yet was deposited in the furrow soon enough so that any dirt rolling back into the furrow would not give an uneven depth of planting. It was necessary to install a jack shaft driven from the regular shaft above in order to drive the plates in the cans on this remodeling job.

Lowering of the cans to the disk furrow opener casting made a complete unit out of the cans and disks so that at the end of the row the can, tube, and disk were raised together.

Last spring the John Deere Company put out an experimental 6-row drill built along similar lines and of course a better mechanically built drill than was obtained on the remodeling.

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[1]Manager, Great Western Sugar Company, Fort Collins, Colo.

Both of these drills give very satisfactory results in the distribution of the seed without sacrificing the ability to use the implement as an all-purpose drill.

For the intermountain districts, or any district where other crops such as beans, peas, soybeans, corn, etc. are grown, growers need an all-purpose drill adaptable not only to beet planting but to other crops. This principle, I believe, also applies to the manufacturers in order to give them a volume of production. A can-type drill with plates for use on other crops seems to meet the needs of the growers.

Such a drill should embody the following features:

1. Can-type drill with changeable plates quickly converted from small, smooth tube to standard spiral tubes or vice versa. Beet plates should have slightly tapered holes 1/64 inch greater in diameter than the size of the larger seed. Thickness of plate not greater than 8/64 inch for the 7-10 seed. This thickness could, I believe, be also used for 7-9 seed.

Plates should be accurate in the spacing of the holes and carefully machined. For beet planting a small stainless-steel tube not more than ½ inch in diameter should be used.

2. Low cans set down on top of the disk furrow opener casting, making a complete unit of the can and furrow openers. No apparent difference has as yet been found in the distribution of the seed using the high-can, long-tube or low-can short-tube, both discharging the seed below and immediately under the hub of the disk furrow openers. However, in the operation of the drill in the field, unless the tube is fixed so that it will telescope, care must be exercised in turning around at the ends of the field. In converting drills now in the hands of the growers the long tube, leaving the cans in their present positions, makes a very satisfactory drill. However, in the production of new drills, certainly the low can makes a better mechanical drill.

3. A wide range in gear ratio should be provided giving different seeding rates, not only for beets but for other crops. For the beet crop it should be possible to get as low as 1 pound per acre.

4. Disk furrow openers. A difference of opinion exists on the merits of the disk furrow opener and the shoe furrow opener. I believe that practically all tests in the intermountain area and certainly in Great Western territory show better germination results with the disks.

5. Depth bands on disk furrow opener should be easily attached or removed. Three sets of bands should be furnished with the drill, 1 inch depth, 1-¾ inch depth, and 2½ inch depth.

6. Chain drive should be eliminated wherever possible and gear-to-gear drive used. All chains should be of the roller type.

7. Steel sprockets should be used. It is very desirable that wear on both chains and sprockets be held to a minimum.

8. Press Wheels. On most of the work on improvement of drills, the press wheels have been neglected. It is possible that some improvement can be made.

8. The furrow planting--planting 2½ inches deep and removing an inch of soil, or the ridging of dirt over the seed covering the row with about 3 inches of dirt, have merit under certain conditions. Attachments for either of these methods should be available in the hands of the dealer, not necessarily being furnished with the drills.

The type of drill just described does not make too radical a change from the present plate drills of all makes and it should again be emphasized that it will give very satisfactory results in the drilling of beet seed and still can be used for other crops.

It is unfortunate that under present conditions the implement companies will not be able to put many new drills on the market. The immediate problem is to convert in some way as many as possible of the drills now in the hands of the growers so that better results may be obtained in the distribution of the seed in the row.

Methods For Reduction of Hand Labor In Spring and Summer Work

J. B. Bingham[1]

I feel we are on the march to bright horizons and it is indeed inspiring to me to note the efforts of so many men dedicated to the single objective of reducing the need for hard human efforts in producing the sugar beet crop. We are each of us attacking the problem from different angles: seed breeding, perfecting the segmenting process, developing more accurate drilling machines, perfecting harvesting machines, using better fertilizers and better soil handling, to name only a few. Surely these efforts cannot help but revolutionize the industry and bring it into its proper relation with other crops and remove from it the slurs and innuendoes that have been hurled at it, perhaps with some justification.

I wish to discuss briefly the cross cultivation method for reduction and possible elimination of hand labor in blocking, thinning, and hoeing as practiced in standard sugar beet culture (and referred to in this paper as old method), and results attained in the Valley of the Red River of the North in northwestern Minnesota and northeastern North Dakota. In this area crops depend entirely on rainfall (about 19 inches yearly average), there being no irrigation water available for general utilization. This cross cultivation method is by no means experimental but has been applied since 1929 in our area as standard field practice each year on acreages as high as 36,000 acres of beets in recent years. More than 300,000 acres of beets have been cross cultivated in this area alone since the start of this practice, which now is extending rapidly into other beet-producing areas.

We have found that acres worked per laborer have been increased, thus reducing labor demand, that soil tilth has been improved, that moisture has been conserved by the heavy mulch placed around each plant in the row, and of very great importance that if weather interferes thinning can be delayed with but little resultant tangling of the roots left in the blocks. Furthermore, the entire acreage on any one contract can be planted in one planting instead of two or three, as is customary in standard beet-growing operations. This utilizes the growing season to fullest advantage and results in increased beet yields.

Yields have not been decreased because of the lessened number of beets per acre; on the contrary they have been increased to around 10.25 tons yearly average (including drought years) with many grow-

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[1]District Manager, American Crystal Sugar Company, East Grand Forks, Minn.

ers producing year after year yields of 12 to 15 tons per acre. The cross cultivation method consists merely of crossing the beet rows at right angles with disks and knives or duckfeet with slight suction. The disks are used mainly to establish the blocks, and the knives and duckfeet are used to kill all growth between the rows or between the blocks. As narrow a block should be left with the disks as possible, preferably from 2 inches to 4 inches wide, with the same center-to-center spacing as the drill rows. This method was started with drill rows initially ranging from 20 to 24 inches apart. Within a very short time drill rows were reduced to a standard of 18 inches apart so that after crossing we now leave blocks 18 inches center to center. This 18 by 18 square pattern gives a plant population of 19,360 beets per acre on a 100 percent calculated stand. At least two cross cultivations are made, disks being used to establish the blocks, with suitable knives or duckfeet set at slight suction to eliminate all growth between the blocks. First cross cultivation is done just before thinning when the blocks are established and again just before hoeing. This is in addition to the cultivations down the row. It is most important that loose dirt be forced back into the disk cut to prevent undue moisture loss. We have found that early cultivation work down the rows and across is advantageous, because aeration resulting from this operation does a great deal to stimulate the growth of the seedling plants. The experience of our growers has been that once the tools are properly adjusted to leave the desired width block and to cultivate the field efficiently and destroy weed growth, it is best to cross the field when the beets are in the two-leaf stage, not looking backward until the job is done and then only after 2 or 3 days.

To avoid moving the beet-containing block (which is likely to happen when narrow blocks are left), it may be necessary to place one disk on the front of the front cultivator bar and the other on the rear of the front cultivator bar. This stagger effect has worked out quite satisfactorily for our conditions. For irrigated areas, where beet stands are irrigated up, it might be desirable to cultivate in the irrigation furrows before starting to cross-block the field.

This cross cultivation eradicates all weeds in about 75 percent of the drill row, and the only hoeing left to do is immediately around the blocks of beets remaining in the row. The direct result is an increased efficiency on the part of labor. In table 1 results are given of time studies made in man-hours required per acre.

Where whole seed was planted and cross cultivating of beets was done, a reduction in man-hours required in blocking, thinning, and hoeing beets resulted, the reduction being from 41.9 hours per acre to 20.97 hours per acre, or 50.04 percent. With the advent and general

Table 1.—Savings made in man-hour requirements per acre in thinning whole and segmented seed, Cross-Cultivated and old method practice.

	Whole seed		Segmented seed
	Old method, 1939 data from Fort Collins, Colo.	Cross cultivation, 1939 data, 14 growers Red River Valley	Cross cultivation, 1943 data, 40 growers Red River Valley
	hours	hours	hours
Thinning	32.30	16.47	10.37
Hoeing	9.60	4.50	5.74
	41.90	20.97	16.11
Percent	100%	50.04%	38.45%

usage of segmented seed, the man hour requirements have been still further reduced to where it now takes 16.11 hours labor per acre, or only 38.45 percent of the time required for these operations by the old method of beet handling.

We used check-row drills for a number of years until segmented seed came into the picture when growers again began drilling seed in continuous rows. We, like everyone else, used the special plates developed by the drill manufacturers which reduced the amount of seed per acre but **did not** place the seed balls in the row evenly spaced; this even spacing in the row is essential in cross cultivation work. (Smooth tubes were not used.)

Our agricultural staff began working in 1942 with H. C. Rassman of the Diamond Iron Works of Minneapolis in developing a drill that would space beet seed evenly in the row. These efforts were successful enough to get these drills into sizable production and we will have about 100 of them in operation in 1946.

Extensive field trials on commercial-sized fields varying from 5 to 15 acres each will be conducted in 1946 using various seed spacings in the row, narrowing the blocks left after cross blocking to as small as 2 inches wide if stands permit. No hand thinning and only such long-handle hoeing as seems to be necessary around the blocks will be done. Critical studies will be made on each field, such as stand counts before and after crossing; data on man-hours required in hoeing, together with at-harvest yields, will be obtained.

Out of these studies should evolve a practical plan that will enable that area to reduce still further the labor demand for spring and early summer operations.

Cross Blocking Studies on Yield of Beets and Reduction of Hand Labor in Southern Colorado

C. W. DOXTATOR[1]

Mechanization of field operations with sugar beets has been a subject for experimentation for many years in southern Colorado. As early as 1928 the research department of the American Crystal Sugar Company conducted experiments of cross blocking and hand thinning as compared to hand thinning alone, and found a slight increase in yield of beets in the cross blocked plots. In 1931 and 1932 in tests conducted by the United States Department of Agriculture and reported by Skuderna et al *(1)*[2], yields of cross blocked and thinned beets were higher, but not significantly so, than those which were hand thinned. In 1939 experimental work conducted by the Company showed that at least 19 percent of hand thinning labor could be saved by cross blocking whole-seed plantings with ordinary cultivator equipment.

1942 Experiments

A 13-acre field was used in 1942 for mechanical blocking and thinning studies. This Experiment was in cooperation with the United States Department of Agriculture. Five rates of planting were used as follows: 3 pounds, 5 pounds, and 7 pounds of segmented seed per acre; 11 pounds per acre of whole seed (using single-seed plates), and 17 pounds per acre using standard plates. Each of these 5 plantings was made in 16-row strips replicated 3 times. Because of adverse spring weather the seed bed was very cloddy and the planting was delayed until April 29. Counts taken after emergence showed an extremely uneven stand.

Cross blocking and thinning treatments were planned as follows: (1) cross block 2-inch cut, 4-in block followed by long hoe; (2) cross block 1-inch cut, 2-inch block, followed by long hoe; (3) long hoe only; (4) check, hand thinning. These treatments were in two replications as bands across the planted strips, each band being 60 feet wide. After the mechanical blocking was completed, time studies were made on the long handle hoe thinning and the hand thinning in the checks, for all plots.

Yield data were obtained by harvesting 65 feet of row in each plot. Sucrose percentage was obtained from two 20-beet samples per plot. Because of extremely poor initial stands (caused by flooding), the plots planted with 3 and 5 pounds per acre and cross blocked 1-inch-

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[1]Plant Breeder, American Crystal Sugar Company, Rocky Ford, Colo.

[2]Italic numbers in parentheses refer to literature cited.

Table 1.—Thinning time and beet yields in 1942 mechanical blocking experiment, Rocky Ford, Colo.

Treatment No.	Planting rate per acre, pounds	Type of seed	Method of:		Percentage time required for thinning	Tons beets per acre	Percentage sucrose	Pounds sugar per acre
			Blocking	Thinning				
1	3	Segmented	....	Long hoe	36.1	16.36	14.80	4,886
2	5	Segmented	....	Long hoe	42.6	16.67	16.05	5,363
3	7	Segmented	....	Long hoe	56.3	16.23	16.30	5,307
4	11	Single whole	....	Long hoe	50.8	16.90	16.22	5,484
5	17	Whole	....	Long hoe	57.4	15.14	16.08	4,875
6	3	Segmented	....	Hand thin	59.0	17.62	15.92	5,611
7	5	Segmented	....	Hand thin	77.1	18.13	16.13	5,825
8	7	Segmented	....	Hand thin	86.9	17.16	16.03	5,463
9	11	Single whole	....	Hand thin	92.9	17.74	15.75	5,593
10	17	Whole	....	Hand thin	100.0	16.34	16.25	5,314
11	7	Segmented	2"-4"	Long hoe	47.0	17.13	15.55	5,315
12	11	Single whole	2"-4"	Long hoe	60.6	15.83	15.70	4,964
13	17	Whole	2"-4"	Long hoe	57.9	14.54	16.62	4,813
14	7	Segmented	1"-2"	Long hoe	36.1	12.24	15.31	3,815
15	11	Single whole	1"-2"	Long hoe	51.4	12.69	16.17	4,103
16	17	Whole	1"-2"	Long hoe	53.0	13.43	16.28	4,397
Significant difference (odds 19:1)						2.81	1.20	978

2-inch and 2-inch-4-inch had to be abandoned. Results of the test are given in table 1.

In this test the time required for thinning beets was reduced by planting segmented seed at proper seeding rates and by the use of (a) long handle hoe thinning on thin stands and (b) cross blocking and long hoe on thick stands. Although differences required for significance are high because of the extensiveness of the test, it is noted that a 5- or 7-pound planting rate per acre followed by a 2-inch-4-inch blocking and long hoe, or long hoe alone (treatment numbers 2, 3, 11), produced sugar per acre yields of 5,363 pounds, 5,307 pounds, and 5,315 pounds respectively, as compared to the check (treatment number 10) of 5,314 pounds. The hand labor required in these three treatments for thinning was 42.6, 56.3, and 47.0 per cent, respectively, of the check.

1945 Experiments

Two experiments on mechanical blocking were conducted in 1945 by the American Crystal Sugar Company. Field A was planted for tests of the Dixie Beet Chopper and Field B for cross blocking using knives and duck feet. In Field A a new International four-row drill was used to plant segmented seed in two replications of 16-row strips. In Field B the Rassmann precision beet drill was used to plant segmented seed at 2 different rates in 2 replications of strips 12 rows wide. American Number 1, seed segmented 7/64 to 10/64 inch and germinating 88 percent was used in both experiments.

Pre-thinning stand counts made in Field A were as follows:

Type of seed and planting rate per acre	Number of beet-containing inches per 100					Percentage of inches with single plants
	Total	Inches per 100 with:				
		1 plant	2 plants	3 plants	Total plants	
3.01 pounds	22.7	18.6	4.0	0.1	26.8	81.9
4.67 pounds	30.2	24.0	5.8	0.4	36.8	79.5

For the 3.01 pounds planting rate, the Dixie Chopper was set for 3-inch cut, 3-inch block, and for the 4.67 pounds planting rate the set was 4½-inch cut, 1½-inch block. This blocking was designed to leave 105 to 115 beet-containing blocks per 100 feet of row. Eight of the 16 rows of each strip were blocked and not thinned and the other 8 rows thinned by hand as a check. One extra hoeing operation to eliminate weeds was required on the blocked plots. Total harvest of each strip was made for yields, and sucrose percentage was obtained from six 10-beet samples in each strip. The data are given in table 2.

It will be noted that a higher sucrose percentage was obtained from the mechanically handled strips, but in the 3-inch cut 3-inch block

Table 2.—Yield obtained from mechanically blocked and thinned strips as compared to hand blocked and thinned strips, Rocky Ford, Colo., 1945.

Pounds segmented seed planted per acre	Treatment	Yield data		
		Tons beets per acre	Percentage sucrose	Pounds sugar per acre
3.01	Mechanical 3"-3"	19.08	17.30	6,602
3.01	Hand labor	22.32	16.44	7,339
4.67	Mechanical 1½"-4½"	20.68	17.24	7,130
4.67	Hand labor	21.60	16.40	6,954

there were too many plants in the blocks, and thus a lower yield was obtained. The net labor saving on the mechanically handled strips was the hand thinning, less one weed hoeing operation.

In field B the prethinning stand was as follows:

Type of seed and planting rate per acre	Drill used	Beet-containing inches per 100					Total plant population per 100 inches	Percentage of Inches with single plants
		Total	Inches per 100 with:					
			1 plant	2 plants	3 plants	4 or more plants		
Seg. 4.93 lbs.	Rassmann	27.5	21.6	5.7	0.2		33.6	78.5
Seg. 7.78 lbs.	Rassmann	44.8	30.3	13.1	1.3	0.1	60.8	67.8

From these counts it was calculated that the cross blocking for the 4.93-pound planting should be an average of 2-inch blocks and 6-inch cuts, and for the 7.78-pound rate an average of 2.5-inch blocks and 10.8 cuts. In the blocking, adjustments were made of the tools on the tool bars of the tractor so that the tractor wheels would not go over blocks. All four strips were crossed using knives with the above two blocking arrangements. Each blocking band was 107 feet wide, and two replications were made. No thinning was made on the blocked plots, nor was it necessary to make an extra weed hoeing operation. A 107-foot band of the four planted strips was hand thinned for a check treatment.

Stand counts, using 100 feet of blocked row, were made in each plot after blocking. At harvest 200 feet of row from each plot were harvested, and marketable and non-marketable beets were selected and weighed. Two 10-beet samples of marketable beets were taken for sucrose percentage from each plot. The data obtained are given in tables 3a and 3b.

The data obtained in both Fields A and B demonstrate that cross blocking to final stand without loss of yield can be achieved. However, this result was not obtained on certain of the planting rates and blocking methods, indicating that very careful study must be given to the pre-thinning stand so that the proper blocking method is used. When a high count of beet-containing inches in the pre-thinning stand is

Table 3A.—Stand counts after mechanical blocking or hand thinning, Field B, 1945.

Blocking and Thinning Method	Blocked or thinned stands per 100 feet of row							
	Total beet-containing hills		Hills per 100 feet with:					
	Possible	Obtained	0 plants	1 plant	2 plants	3 plants	4 or more plants	Total plants
2.5"-10.8"	90	70	20	25	26	13	6	141
2"-6"	150	97	53	55	29	8	5	157
Hand thin	....	112	0	109	3			115

Table 3B.—Yield data from mechanical blocking, and hand thinning, Field B, 1945.

Blocking and thinning method	No. marketable beets per 100 feet of row	Tons beets per acre	Percentage sucrose	Pounds sugar per acre
2.5"-10.8"	93.5	13.71	17.39	4,755
2"-6"	90.5	11.23	18.41	4,144
Hand thin	94.3	13.77	17.45	4,806
Significant difference (odds 19:1)		2.04	.78	691

obtained, blocks can be reduced in width and cuts made wider, thereby reducing hill populations to an acceptable level. The 1945 experience indicates that severe losses will be obtained if the blocks obtained have too high a population of beets.

The blocking methods which produced yields equal to hand thinning left a large percentage of double (and occasionally triple to quintuple) plant hills. The beet population at harvest contained a higher than normal proportion of unmarketable beets. Such stands would increase the amount of topping labor required but can be handled satisfactorily with some mechanical harvesters.

Conclusions

The 1942 experiments demonstrated that segmented seed planted 3 to 5 pounds per acre could be thinned with a long handle hoe, or by cross blocking plus long handle hoe, without reduction of yield of sugar per acre when compared to normal planting rates of whole seed with hand thinning. By the use of these methods, hand work was reduced by approximately one half.

The 1945 experiments have indicated that it is possible to block to final stand with the Dixie beet thinner, or by across-the-row blocking, thereby eliminating thinning labor and with little or no reduction in yield. To attain this result, however, most efficient farming must be practiced.

Further study on seed, drills, and planting rates with blocking methods is necessary before complete elimination of thinning can be generally accepted.

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Time Studies on Saving of Labor in Summer Work[1]

RICHARD W. BELL[2]

To date only an inconsequential part of the summer sugar beet work in the eastern area has been done mechanically. This apparent lag in mechanization exists not because of indifference to the great need for mechanical blocking nor because of a belief that mechanical blocking is not feasible in the East. Rather, it exists because eastern beet technologists quite generally believe that the need for labor saving in blocking and thinning, great as it is, is not as urgent today as is the need for labor saving in harvest. As a consequence, the summer phase of mechanization has not been pressed as intensively as has the fall phase. Had sufficient personnel been available during the war years the problem of mechanical blocking and thinning, in all its ramifications, doubtless would have received more attention.

In addition to the reason given for lagging mechanization of summer work, there is the problem of obtaining uniformly good stands of seedlings grown from single-germ seed. Plans to eliminate hand work from blocking and thinning are based upon attainment of seedling stands characterized by single plants spaced more or less uniformly in the row. To date, such stands are not consistently attained by farmers in the eastern area. This is not purely a mechanical problem. Frequently, attempts to obtain a uniform stand of single seedlings have failed because, first, the planter failed to place the seed uniformly in the row, and, second, seedlings in portions of the field failed to emerge because of black root, crusting of the soil, and other less known factors which militate against uninterrupted growth. Once the problems of precision planting, seed germination, and seedling emergence have been solved reduction of hand labor in summer work is certain to follow.

The use of sheared sugar beet seed has become popular with eastern farmers. Over 50 percent of Michigan's 1946 acreage of beets will be planted with sheared seed. During the summer of 1945 Michigan State college, in cooperation with the Farmers and Manufacturers Beet Sugar Association of Saginaw, conducted a time study on the Lee Ferden farm in Saginaw County to determine more accurately the amount of labor saving effected through the use of sheared seed.

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[2]Extension Specialist. The author wishes to express his thanks to R. L. Cook, L. S. Robertson, P. A. Reeve, H. L. Fletcher, and S. T. Dexter for data and material contributed to this paper.

Indirectly, the study is closely associated with mechanical thinning, as will be shown.

Ferden Farm Time Study of 1945

On May 2, 1945, 56 plot pairs, each pair consisting of six 28-inch rows 90 feet long were planted with sheared and unsheared seed as follows: The north three rows of each plot pair were planted with unsheared seed at the rate of 15.0 pounds per acre; the south three rows with sheared seed at an average rate of 4.2 pounds per acre (about 12.4 seed pieces per foot of row). The planter was a type commonly used by eastern growers which places the commercial fertilizer in a band 1½ inches beneath and 1 inch to the side of the seed.

On June 18 a pre-blocking stand count was made of each row. "Pre-blocking stand" hereinafter indicates number of beet-containing inches, expressed as percentage of total inches of row.

On June 23 and 24 the beets were blocked and thinned. Four Mexican workers were employed for this work, two with long-handled hoes and two with short-handled hoes. Thinning was done concurrently with blocking. Records were kept of the time required to block and thin each 90-foot row.

Labor Requirements.—Usual estimates of labor saving resulting from use of sheared sugar beet seed range from 20 to 60 percent. As shown in table 1, the results of this study indicate that under conditions definitely unfavorable for seedling emergence, with a planter which distributes the seed imperfectly in the row, and at the planting rates shown, a saving of slightly more than 30 percent reasonably may be expected. It is believed that the saving of labor can be increased markedly beyond this figure through more nearly uniform distribution of sheared seed in the row. Frequently, the workers encountered "skips" of several feet and hence were forced to leave multiple-plant blocks which required hand thinning.

As noted before, the south three rows of each plot pair were planted with sheared seed at an *average rate* of 4.2 pounds per acre. However, the individual rows were planted with sheared seed at dif-

Table 1.—Amount of time required to block and thin sugar beets grown from unsheared seed and from sheared seed.

Type seed	Average planting rate per acre (28-inch rows)	Time required to block and thin one acre*
Unsheared	15.0 pounds	17.5 hours
Sheared	4.2 pounds	12.2 hours

*Difference required for significance at 5-percent level—1.265 hours.

Table 2.—Amount of time required to block and thin sugar beets grown from sheared seed planted at different rates.

Type seed	Average planting rate per acre (28-inch rows)	Time required to block and thin 1 acre*	Labor saving
Unsheared	15.0 pounds	17.5 hours	
Sheared	6.3 pounds	13.49 hours	22.9 percent
Sheared	3.7 pounds	12.53 hours	28.6 percent
Sheared	2.6 pounds	10.73 hours	38.6 percent

*Difference required for significance at 5-percent level—1.26 hours.

ferent rates. Table 2 shows the effect of planting sheared seed at different rates upon the amount of time required to block and thin. The greatest saving of labor, in terms of the amount of time required to block and thin the unsheared seed plots, was effected when sheared seed was planted at the rate of 2.6 pounds per acre (about 7.7 seeds per foot). The use of sheared seed at the rate of 6.3 pounds per acre (about 18.6 seeds per foot) resulted in a marked saving of labor, though not as great as that effected by the lower rates. Had conditions affecting seedling emergence been more favorable the use of as much as 6.3 pounds of sheared seed per acre doubtless would have resulted in labor saving considerably less than that shown in table 2.

Pre-Blocking and Post-Thinning Stands.—Table 3 shows the pre-blocking and post-thinning stand counts made on June 18 and June 27, respectively. It is interesting to note the relationship which existed between planting rates and stands. A pre-blocking stand of 15 percent (15 beet-containing inches per 100 inches of row), if characterized by seedlings spaced at more or less uniform intervals in the row, constitutes the basis for a post-thinning stand of 100 or more well-spaced beets per 100 feet of row. However, because the seedlings were poorly distributed in this experiment, a pre-blocking stand of 15 percent resulted in a post-thinning stand of only 74.1 beets per 100 feet of row. Clearly, the use of 2.5 pounds of sheared seed per acre, even in seasons distinctly unfavorable for seed germination and seedling emergence, results in a pre-blocking stand adequate for hand blocking and thinning. However, it is imperative that the seeds be uniformly distributed in the row if a satisfactory post-thinning stand

Table 3.—Pre-blocking and post-thinning stand counts.

Type seed	Average planting rate per acre	Pre-blocking stand		Average number of plants per 100 feet of row June 27	
Unsheared	15.0 pounds	43.3 percent		99.7	
Sheared	6.3 pounds	27.1 percent		88.3	
Sheared	3.7 pounds	16.3 percent	19.5 percent	76.6	79.7
Sheared	2.6 pounds	15.0 percent		74.1	

is to be attained and if labor savings are to exceed markedly those shown in table 2.

Although the acre-yields of roots in this experiment were relatively low because of unfavorable weather conditions, and in spite of a decidedly lower post-thinning stand count, the roots from the sheared seed plots outyielded those from the unsheared-seed plots by 6.6 percent, a value statistically significant at the 5-percent level.

Other Studies

In connection with hand thinning following row blocking, interesting data have been obtained at East Lansing. Sheared seed and several combinations of unsheared seed separates having varying percentages of single-germ seed pieces were planted in 4-row plots, each 30 feet long. The two center rows of each plot were used in a time study. In all, there were 31 plots, each replicated 6 times. The entire set of plots first was blocked with hong-handled hoes, with an approximate spacing of 12 inches from center of block to center of block. Following blocking, the two center rows of each plot were thinned by hand. Records were kept of the time required to thin each plot. The results of this study are presented in figure 1.

The correlation that existed between number of multiple-plant blocks per 100 feet of row and hours required to thin the multiple-plant blocks in 1 acre was very high, the coefficient being +0.99. The data further indicate that the time required simply to traverse an acre of beets growing in 28-inch rows, exclusive of thinning, was 3.5 hours. To thin each multiple-plant block required, on the average, an additional 3.32 seconds.

In the eastern area the planting of sheared seeds at approximately 2-inch intervals in the row frequently results in seedling stands which are characterized by 75 to 80 percent single plants. It will be noted in figure 1 that the time required to thin by hand a blocked stand having 25 multiple-plant blocks per 100 feet of row was about 7.8 hours per acre. The latter value corresponds closely with experimental field results obtained elsewhere in the eastern area. Mr. Pere Reeye, agricultural supervisor of the Farmers and Manufacturers Beet Sugar Association of Saginaw, reports that during the summer of 1945 an experienced beet worker using a long-handled hoe was able to block and thin satisfactorily at the rate of 2 acres per day a portion of a field characterized by a 22-percent germination stand and 77 percent single plants. In view of such evidence it appears that weed-free fields characterized by 75 to 80 percent single plants and a germination stand sufficiently high to permit of satisfactory

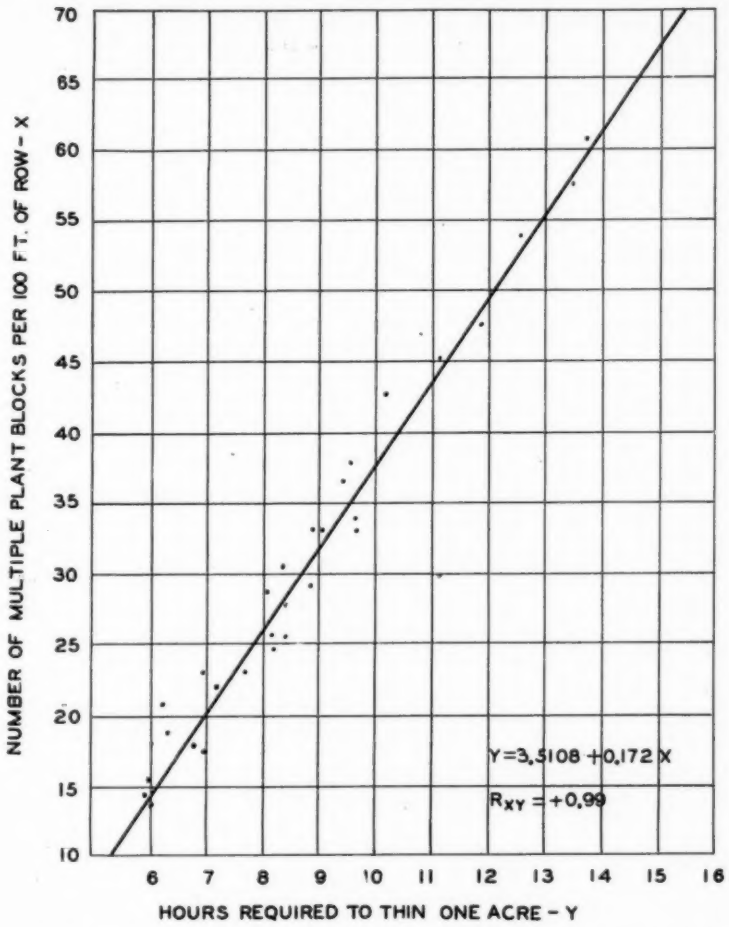

Figure 1.—Relationship between numbers of multiple-plant blocks per 100 feet of row and hours required to thin one acre.

mechanical blocking at 12-inch intervals should be blocked and thinned by hand in preference to mechanical blocking at 12-inch intervals followed by hand thinning. Experimental evidence from the eastern area in the use of mechanical blockers adjusted to leave blocks separated by distances which are a fractional portion of the desired average distance between beets in the post-thinning stand is insufficient at this time to justify its being reported.

The Status of Sugar Beet Harvester Development

H. B. WALKER[1]

Mechanical harvesting of sugar beets is a practical reality even though beset with many difficult problems yet to be solved before hand work is entirely eliminated. In 1945 California growers harvested upwards of 400,000 tons mechanically, representing approximately 30 percent of the crop. Smith (*4*)[2] lists seven mechanical harvesters of importance for 1946 and nine in various stages of development. Of the seven listed as having significance for 1946 growers, three are commercially available through normal manufacturing channels, two are in the pre-production or engineering stage, and two are of the custom built type.

Mechanical harvester acceptance has been favorable from the standpoint of machine development. High wages, low labor supplies, and strong demand for sugar and sugar beet by-products have stimulated growers and processors to accept mechanically harvested roots under tare conditions which would have been unacceptable 10 to 12 years ago under different economic conditions. This influence has been most helpful in mechanization development and may be credited as a war benefit.

The immediate problem before the sugar beet industry is no longer one of feasibility of mechanization but one of programs of development which will bring to greater perfection the mechanization now established. One should not minimize the problems remaining, but on the other hand there are no good reasons for extreme pessimism. The ideal harvester is one that will harvest under any condition of soil, weeds, and weather with 100 percent root recovery and with a minimum of dirt and top tare, with the tops sorted out for convenient handling; all of these operations should be done by one machine, operated by one man, at any rate desired. Experience is telling us that ideals are not likely to be attained and no doubt several types of machines will find places in the market, each with superior performance for the area or condition in which it is predominantly used but none a completely perfect unit.

I propose to discuss briefly some of the trends in present-day design based upon recent developments as I did at the third general meeting of this Society in 1942 (*5*). I shall use the same general order of discussion for machine elements, viz:

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[2]Italic numbers in parentheses refer to literature cited.

1. Preparatory mechanisms such as coulters and disks.
2. Topping mechanisms including "in place" and "in machine" topping.
3. Plows or lifting devices.
4. Elevating mechanisms.
5. Soil-beet separation.
6. Root and top disposal.
7. Drive mechanisms and mountings.

Many present-day harvesters have some type of soil-working mechanism to prepare the beet for topping and lifting; particularly is this so for harvesters using the "in place" type of topper. The function of such mechanisms is to cut off leaf streamers; throw dirt away from the roots to make topping more accurate, fracture the soil adjacent to the roots to reduce clods, and in some cases, provide a more uniform surface for operating the automatic parts of the topping apparatus. The positioning of such mechanisms must be ahead of the topping and lifting units; for tractor-mounted harvesters these are near the front axle (Deere, International Harvester Company, and University of California types). Since such mechanisms must center on the row, and since the plow points likewise must follow on the row, when these two elements are far apart in a direction linear to the row any side draft in the harvester contributes to difficulties in holding the machine on row. Most "in machine" type toppers are able to avoid these mechanisms, but where beets are topped "in place" coulters, disks, and jointers are generally used in pairs, singly, or in combination. These devices undoubtedly influence the problem of keeping on row, and it would appear this is related to the location of the mounting with reference to the guiding members and the linear distance between the preparatory mechanism and the lifter points. This distance should be as short as possible and preferably both units should be within the wheel base of the tractor with the topping unit between.

Row spacing influences the necessity for, and the difficulties with, preparatory devices used on "in place" topping harvesters. Generally speaking the closer the row spacing the greater the necessity for them. Yet the closer the row spacing the more difficult it becomes to operate such units. Row spacings of 20 inches or less are in the critical range. For this reason wider row spacings would be especially helpful for "in place" topping harvesters.

Topping beets mechanically may be accomplished in a number of ways, none of which is perfect, but a relatively large number of meth-

ods are now considered acceptable. It must be remembered that our standards of acceptance are much more tolerant than in years past, a favorable factor for machine development, but our programs for development should be directed toward better performance; viz; a minimum of top tare with a minimum of top loss. Machine topping continues to be of two general types; (a) "in place" or ground topping, and (b) "in machine" topping. Of the seven machines listed by Smith (4) as having importance for 1946, three are "in place" toppers and four are "in machine" types. Of the three in commercial production, one is an "in place" type (John Deere) and two (Marbeet and Scott-Urschel) are "in machine" toppers.

Ground toppers are of the variable cut type, but these vary greatly as to types of finders and knives. Driven finders may be broad or narrow, track type, or small wheel series. In general, driven finders tend to support the beet against the cutting forces of the knife and also provide better resistance to the inertia forces of the movable topping mechanism. For these reasons, driven finders appear to offer advantages over shoe types in securing straight cuts perpendicular to the root axis, particularly where thin cutting blades are used, such as in the John Deere and University of California units. This type of construction, based upon field experience to date, appears to contribute to a superior quality of topping over a wider range of travel rates than toppers with revolving disk blades. The former, however, have more moving parts and are thus more vulnerable to fouling in wet and weedy fields. Furthermore, they require more linear space for mounting. Revolving disk toppers have been and are still popular for "in place" topping devices. These may be used with shoe finders (International Harvester) or track type finders (Catchpole, England). The attractive features of such units are simplicity of construction, compactness of design, ruggedness, and resistance to fouling. The type of knife (disk) requires good on-the-row control to maintain optimum topping. The inherent character of the design limits operating speeds to approximately 2 to 2½ miles per hour for best results, after which topping tare increases rapidly. However, most "in place" type toppers do not permit very high travel rates for good quality of work.

Machine topping of roots has gained in impetus in recent years because of the development of new methods of engaging the tops of plowed beets, such as the Marbeet method, in addition to older systems of engaging beets by their tops as exemplified by the Scott-Urschel unit. Such topping units in themselves do not have so much to recommend them from the single standpoint of quality of topping, but mechanical beet harvesting is a combination of topping and recovery of beets. Because of this, "in machine" topping has gained in

prominence. Basically it is highly questionable if it is possible to position and remove tops from beets after lifting from the soil with as much precision as when the beets are held in place. The success attained by harvesters using "in machine" topping, particularly the Marbeet, when judged by rate of operation and recovery of beets justifies support of this principle for harvester development. Improvements may be expected from greater use of such equipment, and these together with the perfection of milling procedures certainly place "in machine" topping in a position of economic importance.

The past few years have witnessed some design changes in plows or lifters. Generally speaking some modified form of the Colorado lifter is used more than any other single type. It is a favored type among the older established full-line implement concerns and it is well adapted to harvesters using the "in place" type of topping mechanism. Powers[3] has worked out a modification of this general type of lifter with his introduction of the helical plow. This plow performs the dual purpose of beet lifting and soil fracturing, thus showing considerable promise in hard, dry soils. For harvesting under wet conditions further plow modifications may be necessary, or in other words different points may be necessary for use under different soil conditions. Fortunately this requirement need not be a serious deterrent, since points may be designed for quick removal and replacement.

Where "in machine" topping is used, the function of the plow is somewhat different. Here the plow loosens the beet from its soil environment in a way to permit its removal through some form of top engagement. The form of plow may vary considerably, as for example, a single-point tongue type is used in the Scott-Urschel harvester, while a double-standard chisel-type lifter is used on the two-row bed-type Marbeet harvester. The latter machine probably holds the record for the greatest tonnage of mechanically harvested beets in 1945. It is apparent many problems remain in plow design, both in the points themselves and in the positioning of these points in the machine with reference to other functioning parts of the harvester.

The method of engaging the beet by the tops other than between inclined chains is a recent development brought into commercial application in the Marbeet machine through the development of cycloidal spikes extending outward more or less radially from a large pickup wheel. This general idea has been used by others in various modified forms (Bingham-Holkesvig, Great Western, etc.). The necessity of bringing the untopped beet in close contact with the wheel rim

[3]Powers, J. B. Assoc. Agricultural Engineer, California Agricultural Experiment Station, University of California.

so that the spikes engage the loosened beet firmly enough to permit radial lifting places a heavy load on the plow and wheel, thus contributing to heavy draft, but this contributes to a very satisfactory recovery of beets in soils ranging from moist friable to dry lumpy conditions. In very wet soils the wheels tend to "gum up" with the wet earth and the whole unit may become inoperative. While much progress has been made in the development of lifting devices for both moist and dry soil conditions there are many troublesome problems remaining for beet recovery from wet soils.

No one has yet found an entirely satisfactory method of removing plowed beets from the soil and discharging these into a conveyor system under desirable tare tolerances. Here again we are concerned with basic topping and beet removal procedures. Where "in place" topping is followed, the plowed beets may be forced into a cleaning system by one of a number of methods. The one most commonly tried is delivery into some form of chain type conveyor such as is used in potato harvesters. These may be flat types, or V-shaped, or combinations, with or without flights, and frequently in combination with Reinks rolls. In other cases flipper wheels may be employed, such as Deere, or converging wheel pickups of the Maynard (*3*) type. Hammer Brothers[4] used a similar principle as early as 1931. This principle has advantages for quick but incomplete separation of roots from earthy materials. Powers[3] has attempted to engage the roots at the heel of the plow and then drain the soil away. This method has shown promise under a fairly wide variety of soil conditions ranging from wet to dry. The International Harvester Company in their pre-production unit provide a preliminary cleaning over Reinks rolls and chain conveyors and finally resort to a sorting table for final separation when this is necessary. The sorting table idea is not new, but as now employed by this company in combination with other machine elements it puts to practical use an old idea. Armer (*1*) used this principle in development work as early as 1940 with some promise but felt at that time a more complete ground recovery of beets was essential before it could become economically feasible.

Beet losses from ineffective machine recovery continue to be troublesome. Generally speaking, some form of scavenging to reduce field losses continues to be profitable. Where "in place" topping is followed, losses tend to be somewhat higher than "in machine" topping types of harvesters like the Marbeet. The former, however, expose lost beets much better than the latter so that scavenging is not difficult, while with "in machine" topping harvesters losses remain covered up because of lack of tops for proper engagement of the roots to lift these from the ground. While beet losses in the field are frequently much too high, these losses are becoming progressively less.

[4]Harvester demonstrated Longmont, Colo., 1931, by Hammer Bros., Miller, Ohio.

Continued improvement in harvesters no doubt will eventually reduce these to a level where scavenging becomes uneconomical.

The elevating and conveyor mechanisms back of the plow and its related lifting devices serve the dual purpose of beet cleaning and delivery to bulk containers. Potato chain conveyors with flights are used more than any other single type because this type of construction permits easy fabrication and repair and provides at the same time fairly rugged construction with provision for drainage of unwanted dirt. Every advantage possible must be utilized to remove clods and adhering earth. In dry soils clods are the real problem, while in moist to wet soils adhering earth predominates. The sorting belt now used in pre-production models of the International Harvester Company unit; the free drainage system under experimental development by the University of California; the spike pickup system used by Marbeet and others, all tend to reduce the seriousness of the clod problem. In Great Britain a rotating slatted cage is being used as a supplementary cleaner after the form of the "Salleng" (*2*) harvester, a Danish machine developed 15 years ago. Such devices may have advantages in removing earth clinging to beets. It may be well to point out that wet harvesting conditions present one of our greatest unsolved harvesting obstacles. Elevating mechanisms gum up under wet soil conditions and too much soil is carried with the beets to the bulking containers. It would be unfair to say no progress is being made in harvesting beets mechanically under sticky, wet conditions, but we should recognize the need of greater adaptability of harvesters to wet soils if we hope to make mechanical harvesting our sole harvesting reliance. To overcome this obstacle seems to require more engineering on plows, lifting mechanisms, soil drainage devices, and self-cleaning elevators.

Root collection systems must vary with the different types of harvesters. Where high rates of harvesting are possible, direct delivery to trucks is desirable and economical. Large capacity machines, like the Marbeet two-row, function very well in this way, but fields have to be opened up for such machine operations. Various systems are used for single-row units. The pre-production International Harvester Company unit has a trailing bin with cleaning devices which serves as a container for limited quantities of roots and also as a cleaner and transfer bin for truck loading. This type of unit has definite advantages in opening up fields, in the reduction of dirt tare, and in adaptability for medium-sized field operations. The windrow disposal syster used by Deere operates very well under favorable soil environments, but it requires a field loader as a complementary harvesting unit. The system of dumping in piles in the field has never received wide grower acceptance.

Top disposal, particularly in the intermountain areas, has always been a matter of grower concern. The Deere system is probably the most perfect of any yet devised. Disk topping units tend to mix earth with the tops and "in machine" toppers of the Marbeet type have similar disadvantages. Machines of the Scott-Urschel type deliver much cleaner tops. Top collection and recovery is still a secondary detail in the minds of most development engineers, even though it looms large in the minds of some growers. There is no reason to anticipate other than a satisfactory solution to this problem.

Harvesters as built today consist mainly of tractor-mounted and drawn units. The former undoubtedly will predominate in number since single-row units load up most wheel tractors to reasonable limits. In the drawn units power take-off drives may be and are used for single-row units, while the two-row types have independent motor drives. Large manufacturers seem to prefer to develop equipment which may be mounted on or used in connection with their own power units. Small manufacturers of necessity must build drawn equipment. There is plenty of room for improvement in both types, and at the moment neither type seems to possess any overwhelming advantages over the other.

In my 1942 paper I made some predictions relative to future development of field harvesters. Most of the statements I made then still hold. There are new developments today that did not exist 4 years ago. These developments, added to those of 4 years ago, seem to assure this industry an acceptable line of mechanical beet harvesters for practically all grower conditions in the active development years ahead.

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Systems of Doing the Harvesting Mechanically

D. J. Roach[1]

A number of different systems of operation and management will be used in the harvesting of sugar beets mechanically. The wide range of conditions that exist in different parts of the country and from farm to farm will make it impossible for a universal system or scheme to be used. Conditions in California are different from those in the Intermountain and Plains area, and conditions in both of these areas are different from those in the Eastern territory.

The average size of contract alone will make a difference in the kinds of machines that are used and the way in which they are used. I recently determined the average size contract in these several areas. In California the average size contract is 74 acres, in the Intermountain and Plains area it is 20 acres, while in the Eastern area it is 10 acres. Naturally in California with large size contracts and the characteristic use of heavy power, they will use large machines and it will be necessary for these machines to operate more continuously because of their probable greater cost. In the Intermountain and Plains area where the family-size farm predominates and where the farm power is smaller, the tendency will be towards smaller machines owned by individual farmers or owned in some cases by two farmers. There will also be in this area some custom work done, probably by farmers with small acreages who own a machine and want to make a greater return on that machine than they can harvesting on their own farms alone. In the Eastern area where the small beet acreage is the rule, I would expect that custom work will become more general than is true in either of the other two areas.

The length of the harvest season will to a considerable extent determine the manner in which harvesting is carried on. In California, where the harvest extends in normal years for 90 days or more, fewer total machines per 1,000 acres of sugar beets will be needed to do the work than will be true in the Intermountain and Plains area and the Eastern area where the harvest must be completed before freezing weather sets in, or within about 30 days.

The different practices in the conservation of the tops will, to some extent, determine the type of machine that will be used. In the Intermountain and Plains area, and I think properly, much emphasis is placed on complete conservation of the tops. In that area it is be-

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[1]Vice President and Assistant General Manager, Great Western Sugar Company, Denver, Colo.

lieved that all the fertilizing elements in the tops can be returned to the soil through barnyard manure and at the same time a substantial amount of meat produced in the feeding of these tops to livestock. In the overall agricultural economy of the Intermountain and Plains area the sugar beet tops have a feed value that cannot be overestimated, and the ultimate machine must make provision for the best possible conservation of these tops. In this area the lands do not have the great natural fertility of some of the other areas, and in order to maintain a long-time successful agriculture there must be a feeding industry tied in with the farming operations. The sugar beet tops in themselves provide the basis for this feeding industry. In California not as much importance is placed upon the tops, although it is my own judgment that as time goes on more and more emphasis will be placed upon tops conservation in that area. In the Eastern area the importance placed upon sugar beet tops is about half way between the other two areas. In this area as in California, it is my belief that fuller recognition of the value of tops will be true in the future than has been the case in the past. What I want to say in this connection is that regardless of what the present practice of handling tops may be in these areas, machinery manufacturers will do well to give serious consideration to sugar beet top conservation.

The development of harvesters which can be used on only one type of tractor will slow down the universal use of sugar beet harvesting machinery. The farmer who desires a sugar beet harvester cannot in every case change over to a new type of tractor. I think that in the overall development, manufacturers should give consideration to building machines that can be attached to other than their own particular make of tractor.

The question of whether the beet harvester should be of the one-row or the two-row type is not yet clearly defined. My own judgment is that both of these types of harvesters will ultimately be used. For the grower of relatively large acreage who has plenty of hauling equipment and who has a full appreciation of the value of the tops, I anticipate the use of the two-row harvester in which the topper and the harvester are two separate units. The beets will be topped by the two-row topper and the tops delivered directly into a truck and taken to the silo. The two-row harvester will follow, with the beets being delivered directly into the truck and delivered to the receiving station. Naturally this scheme will require an abundance of hauling equipment. The large grower will have this equipment available, and in some cases the smaller growers will combine to furnish the necessary hauling equipment. Many farmers, however, will not have this hauling equipment available or may not have the power to pull a two-row harvester. They will naturally use the one-row harvester.

The subject of management in beet harvesting could easily take up a whole morning session, but much of that discussion would be conjectural and theoretical. We are just on the threshold of mechanical harvesting of sugar beets, and the American farmer with his usual canniness and ingenuity will work out and evolve those systems of management that best meet his own individual conditions. I have tried only to bring out some points that I believe need consideration in the development of sugar beet harvesting practice.

Mechanical Beet Harvesting From the Eastern Point of View

CLARENCE HANSEN[1]

Beet growers in the eastern area experienced unusually wet soil conditions throughout the harvest of 1945, with the bulk of the rain coming early in the fall. The rainfall was not far above normal but the cloudy days were so numerous as to prevent the heavy Brookston clay soils upon which much of the beets are grown from drying out. This prevailing adverse condition in many cases hampered the successful operation of beet combines.

Two types of combines were operated in the eastern area during the 1945 season. One lifts the beets and carries them to the topping mechanism, and the other uses a ground topper. The former will be referred to in this paper as the lifter-topper type.

The 16 beet combines used accounted for less than 1 percent of the harvested acreage. Fourteen were of the lifter-topper type and two were of the ground-topper type. Two of the harvesters were operated experimentally and were not striving for acreage. The acreage harvested by the machines ranged from 10 to 100 acres each.

Soils upon which Combines Operated

The combines harvested beets grown on a wide range of soil types. They include the various types of Brookston soils, which are heavy clays, the numerous loams such as the Miami, Brady, and Conover, and the Carlyle muck.

Michigan has 100,000 acres of muck, a friable organic soil, upon which the sugar beet crop fits well into crop rotation plans. The lifter-topper type has worked quite successfully upon this soil because, as we stated, it first lifts the beets and then tops them. This fact can be borne out by the acceptable tare figures of beets raised on muck shown in table 1.

The ground-topper harvesters did a very acceptable job of topping on the firmer soils such as the Brookston clays and the clay

[1]Agricultural Engineering Department, Michigan State College, East Lansing, Mich.

Table 1.—Results of 1945 beet harvesting trials with elevator-lifter type combine.

Soil type		Percent soil moisture	Percent dirt tare	Percent crown tare	Percent tare total	No. beets per 100 feet	Marketable beet tisuue left in field per acre				Tractor used on combine	Speed m.p.h.	Estimated tonnage per acre	Percent dirt in load
							Whole beets		On tops weight tons	Total weight tons				
							Number	Weight tons						
A	Muck	98	3.5	2.5	6	67	186.7	.100	.49	.650	IHC H	4.25	16.5	13.
B	Muck	87	5	3	8	65	186.7	.244	.127	.371	Oliver 70	4.55	15.	8.2
C	Brookston	19	4.5	7.5	12	98	1,120.	1.120	.397	1.517	Oliver 70	4.55	16.	23.4
D	Brookston	28	5.5	8.5	14	65	933.5	1.295	.187	1.482	IHC M	4.25	13.	30.7
E	Brookston	17	5	9	16	81	93.3	.128	.583	.711	IHC M	4.25	12.	18
F	Brookston Inclination	20	9	2	11	85	0.0	0.0	.023	.023	IHC H	4.25	6.8	25
G	70 Percent Brookston	14.5	8	2	10	88	186.7	.327	.093	.420	IHC H	3.5	15.6	8.6
H	Miami Conover	22	10	2	12	68	0.0	0.0	.298	.298	IHC H	3.5	4.6	19.1
I	Miami Brady	12	11	2	13	100	1,120.0	.466	.093	.559	MH Sr.	3.75	7.	12.9
J	Miami Brady	13.4	10	2	12	100	2,613.8	1.306	.224	1.530	MH Jr.	3.75	7.	15.

loams. This harvester has an ideal set-up for windrowing the beets and, of course, that is how they were operated. One of the Michigan growers fitted his lifter-topper combine with a windrowing device, and since he had low-yield beets and was 30 miles from the weighing station, this plan of beet handling worked successfully. However, the remainder of the lifter-topper combines loaded the beets directly into the vehicle which either hauled the beets to the weighing station or dumped them into piles in a suitable place for reloading.

Many combine operators with the exception of those who harvested beets grown on muck encountered much difficulty with stones getting into the mechanism, causing breakage and frequent short stops while the stones were being removed. The little stones gave the most trouble to the lifter-topper combine because they would be picked up by the dirt adhering to the beet root and carried into the machines. Recommendations have been made to remedy this source of trouble.

Testing Program

Michigan State College has been cooperating for the past 3 years with the Farmers and Manufacturers Beet Sugar Association and the U. S. D. A. to further the mechanical harvesting of beets. The 1945 season embodied a program of testing and developing principles applicable to mechanical harvesting. The included chart (table 1) is a self-explanatory summary of the testing program. It will be noted that there is an interesting correlation between the soil moisture content and the percentage of dirt hauled back by the trucker or grower from the weighing station. This relationship is shown graphically in figure 1.

The data shown in table 1 were obtained in the following manner. After the field in which the harvester was working had been looked over, two 100-foot portions of rows were marked out in what appeared to be a typical part of the field; the included beets were then counted. The soil moisture content was determined from a sample taken to the depth of 6 to 8 inches in the beet row. After the combine passed the marked portion of the row, the tops were gathered and the marketable tissue cut from the crowns and weighed. All marketable beet-tissue figures are calculated on an acre basis. The tare figures, as well as those with respect to dirt hauled back, were obtained from the tare men at the weighing station from the load which hauled the "test run" beets. In all test runs the beets were hauled directly from combine to weighing station.

Limited similar tests were run on hand-harvested beets. It was quite obvious that beets from the combines were more uniformly topped than were the hand-topped beets. These tests indicated that if the laborers were unfamiliar with the crop there was much more marketable beet tissue left in the field when hand topping was used.

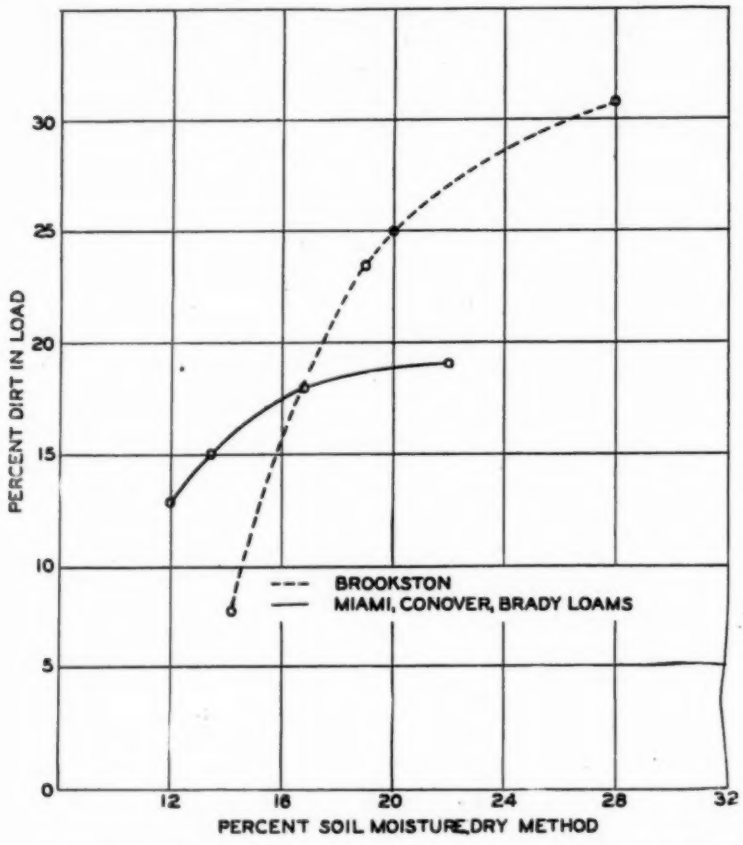

Figure 1.—Effect of soil moisture and type of soil upon percent of dirt hauled back from weighing station when using the Scott-Urahel harvester, loading directly into the vehicle.

Cost of Operating a Combine

If we are to make the data related to mechanical harvesting complete, we must consider the cost of mechanical harvesting. At the present purchase price of combines, allowing for their depreciation, interest, taxes, and housing, and the cost of maintaining a tractor plus the wages of two operators, the total cost should not exceed $12 per acre. A few of the growers who have harvested an annual acreage nearing the 100 mark computed their costs at about $9 per acre. In view of these figures and the present hand-harvesting rates in Michigan, it would be financially sound for a grower to purchase $1,500

worth of mechanical harvesting equipment for an annual production of 25 acres of 12-ton beets.

Capacity of the Harvesters

The two makes of harvesters operating in the eastern area have a limiting factor in that they are one-row machines. Growers operating the lifter-topper type machines report that they are able to harvest up to 5 acres per 8-hour day on 28-inch row beets, and operators of the ground-topper harvesters report a daily acreage of 3 on the same width rows.

Windrowing Beets and Loading Direct

As has been stated, much of the eastern combined beets were hauled directly from the machine to the weighing station. Yet there is a definite need for a machine which will windrow or pile the beets prior to hauling. Growers who have stands less than 5 to 7 tons per acre would find it impractical to drive a truck or draw a wagon next to a harvester for loading. Also, because it is advisable to keep a combine in continuous operation throughout the harvest season, the grower with heavy yields whose fields are more than 20 miles from the weighing station would find it impossible to maintain sufficient transporting facilities. Only the growers who have a comparatively short distance to travel have found it financially successful to carry out the practice of direct loading. There are two more points to consider on this matter—(1) It is found that beets which have been windrowed or piled and reloaded contain from 10 to 15 percent less dirt than those hauled directly from the machines; (2) piled beets may shrink approximately 12 percent by weight in 9 days or 18 percent in 16 days.[2]

Conclusion and Summary

Michigan State College called a meeting on December 27, 1945, of many men interested in sugar beet mechanization. At that time the fact was emphasized that as far as the eastern area was concerned the development of mechanical harvesting should take precedence over the mechanization of the Spring and Summer work. This is indeed reversing the chronological order, but it has been found that many of the migratory laborers which have been available for the planting and growing of the crop are not in the area during the harvest season. Had it not been for the German prisoners of war, many more acres of beets would not have been harvested in 1945.

[2]From unpublished data courtesy J. G. Lill U.S.D.A.

At this same meeting there was a thorough discussion of mechanical harvesting difficulties in the eastern area, and many concrete suggestions were made for their solution. It was found that three main difficulties confronted the grower. They are (1) numerous mechanical weaknesses in the present combines; (2) under wet soil conditions, an excessive amount of dirt in the loads of beets loaded directly from the combine; (3) an apparent excessive amount of leaves and trash in the load. An accelerated program was set up at that time for their solution.

This program is in part as follows:

1. Make recommendations to combine manufacturers for the elimination of mechanical deficiencies.
2. Study, under field conditions, a number of existing combines in early Spring with a view toward their possible introduction into the eastern area.
3. Continue and improve the present program of investigating and testing available machines during our harvest seasons.
4. Continue search for basic ideas and principles which will aid the harvesting program.
5. Promote an interest in mechanical harvesting among beet growers.
6. Assist in an educational program to help growers and processors to make the best use of the mechanical harvesters.

Future of Mechanical Harvesting in Eastern Area

Interest in mechanical harvesting runs high with the eastern grower. This fact was borne out by the success of the open forum on the subject of the Ohio and Michigan Annual "Sugar Beet Days." Farmers are anxious to rid themselves of much o. the laborious tasks connected with the growing of the crop. It is for these reasons and others that the supply of combines will fall far short of the demand. All this plus the comparatively low harvester operation costs and the saving of marketable beet tissue are reasons why many growers and processors are quite willing to accept the work of the present harvester.

Report of the Treasurer

I herewith submit the Treasurer's report covering the 4-year period, January 1, 1942 to December 31, 1945.

Receipts

Convention banquet, Salt Lake City	$ 572.50
Convention registrations, Salt Lake City	35.00
Individual memberships (inc. 1942 Proceedings)	697.33
Company memberships	100.00
Sale of Proceedings ('37, '38, '40, '42, '44)	364.70
Sale of reprints from 1942 Proceedings	418.79
U. S. Beet Sugar Ass'n (On cost of 1942 Proceedings)	2,550.00
Farmers & Mfgrs. Beet Sugar Ass'n. (On cost of '42 Proc.)	450.00
Loan	50.00
Miscellaneous	12.75
Total receipts	$5,251.07
Balance on hand December 31, 1941	349.80
	$5,600.87

Disbursements

Expense of official guests, Salt Lake City	$ 234.71	
Convention banquet expenses, Salt Lake City	661.70	
Convention expenses, Salt Lake City	86.62	
Cost of 1942 Proceedings (labor and materials)	3,414.49	
Cost of 1944 Proceedings (material and postage)	257.49	
Cost of reprints from 1942 Proceedings	426.87	
Stationery and miscellaneous printing	90.10	
Postage (inc. mailing of 1942 Proceedings)	141.42	
Payment of loan	50.00	
Miscellaneous expenses	43.43	$5,406.83
Balance on hand December 31, 1945		$ 194.04

Respectfully submitted, C. E. Cormany, Treasurer.

Report of the Secretary

The active paid-up memberships in the Society are distributed as follows:

Individual:

Arizona	3	Nebraska	7
California	47	New Mexico	4
Colorado	47	New York	3
Idaho	23	North Dakota	1
Illinois	7	Ohio	6
Indiana	3	Oregon	7
Iowa	2	Pennsylvania	1
Maryland	5	South Dakota	2
Massachusetts	1	Tennessee	1
Michigan	13	Texas	1
Minnesota	3	Utah	32
Missouri	1	Washington	2
Montana	8	Wyoming	6

Total U. S.		236
Hawaii	1	
Canada	13	
England	1	
British Columbia	1	
Denmark	1	
Ireland	1	18
GRAND TOTAL		254

Companies, other than sugar processors 10

These figures show a gain in individual memberships since the last general meeting of 47 in the United States and 5 outside the United States.

In publishing the 1942 Proceedings, the Society was subsidized by the U. S. Beet Sugar Association in the amount of $2,550 and by $450 from the Farmers and Manufacturers Beet Sugar Association. We hereby acknowledge these generous gifts. We also express our appreciation of the services of Mr. Glenn Kinghorn, editor of the proceedings, Miss Esther Horsley, and the Editorial Service of the Colorado A & M College.

The 1942 proceedings were sent to all Society members, sugar and "company" memberships, and to 17 Government experiment stations, 13 university and college libraries, and 3 public and industrial libraries in the United States, and 12 university and industrial libraries outside the United States.

The Society is on an exchange basis for publication with 21 sugar and scientific companies, including Hawaii and 5 foreign countries.

The third regional meeting of the Eastern United States and Canada Sections of the Society was held in Detroit, Mich., January 11 and 12, 1943. A limited number of copies of the proceedings of this meeting were published.

In 1944 the Intermountain and Eastern Slope Section held a regional meeting in Denver, February 1-3. Proceedings of this conference were published and distributed to those in attendance and to others requesting same.

There are now on hand in the Secretary's office the following:

1937	Proceedings	13 copies
1938	Proceedings, Salt Lake City meeting	12 "
1940	Proceedings, Denver meeting (2 vols)	155 "
1941	Summary of Sugar Beet Investigational Work in Canada and United States	61 "
1942	Proceedings, Salt Lake City meeting	590 "
1943	Regional Proceedings, Detroit meeting	5 "
1944	Regional Proceedings, Denver meeting	5 "

Respectfully submitted,

C. E. Cormany, Secretary.

Registrants at A.S.S.B.T. Meeting In Denver, February 12-14, 1946

Carl D. Adams, Sidney, Mont.....Holly Sugar Corp.
M. M. Afanasiev, Bozeman, Mont.....Montana State College
Carl Aikele, Denver, Colo.....Great Western Cugar Co.
P. W. Alston, San Francisco, Calif.....Spreckels Sugar Co.
A. P. Anderson, Saginaw, Mich.....Michigan Sugar Co.
Lyman H. Andrews, Billings, Mont.....Great Western Sugar Co.
Austin Armer, Sacramento, Calif.....Spreckels Sugar Co.
L. J. Arnold, Gunnison, Utah.....Gunnison Sugar, Inc.
Philip Baker, Lethbridge, Alberta, Canada.....Canadian Sugar Beet Producers Assn. & Alberta Sugar Beet Growers
Wayne E. Baker, Sheridan, Wyo.....Holly Sugar Corp.
Homer C. Bailey, Corvallis, Mont.....Grower
Roy Bainer, Davis, Calif.....University of California
R. D. Barmington, Fort Collins, Colo.....Colo. Agric. Exp. Station
B. I. Becker, Windsor, Colo.....Great Western Sugar Co.
Richard W. Bell, E. Lansing, Mich.....Michigan State College
Arthur N. Bennett, Denver, Colo.....Great Western Sugar Co.
Ernest Bennion, Picture Butte, Alberta, Can.....Canadian Sugar Fac., Ltd.
Hobart Beresford, Moscow, Idaho.....University of Idaho
Rudolf Beyer, New York City, N. Y.....Waverly Sugar Co.
L. H. Biggar, Denver, Colo.....Dicalite Co.
A. J. Bigler, Idaho Falls, Idaho.....Utah-Idaho Sugar Co.
J. B. Bingham, E. Grand Forks, Minn.....American Crystal Sugar Co.
R. K. Bischoff, Lovell, Wyo.....Great Western Sugar Co.
E. F. Blackwelder, Rio Vista, Calif.....Blackwelder Mfg. Co.
George P. Bloxham, San Francisco, Calif.....Wilson & Geo. Meyer & Co.
Jas. V. Bluebaugh, Longmont, Colo.....Great Western Sugar Co.
H. W. Bockstahler, St. Paul, Minn.....U. S. D. A.
T. W. Bohmker, Moline, Ill.....John Deere Co.
A. R. Bollaert, Los Angeles, Calif.....Dicalite Co.
Robert Boyd, Vancouver, B. C.....Canadian Sugar Factories, Ltd.
V. F. Bozeman, Moline, Ill.....John Deere Wagon Works
T. W. Bracken, Torrington, Wyo.....Holly Sugar Corp.
J. W. Bressler, Rocky Ford, Colo.....American Crystal Sugar Co.
H. E. Brewbaker, Longmont, Colo.....Great Western Sugar Co.
F. H. Brinkhaus, Denver, Colo.....Capitol Rendering Works
Earl Brookover, Ulysses, Kans.....Grower
Robert J. Brown, Denver, Colo.....Great Western Sugar Co.
F. W. Burgesser, Los Angeles, Calif.....Filtrol Corp.
M. J. Buschlen, Detroit, Mich.....Great Lakes Sugar Co.
H. L. Bush, Longmont, Colo.....Great Western Sugar Co.
Julius Cabutti, Preston, Idaho.....Franklin County Sugar Co.
John M. Campbell, Belle Fourche, So. Dak.....Utah-Idaho Sugar Co.
Sam C. McCampbell, Salem, Oregon.....West Coast Beet Sugar Co.
Collins T. Cannon, Salt Lake City, Utah.....Utah-Idaho Sugar Co.

Rowland M. Cannon, Toppenish, Wash.....Utah-Idaho Sugar Co.
Wilford Y. Cannon, Salt Lake City, Utah.....Utah-Idaho Sugar Co.
Reginald S. Carey, Sugar City, Colo.....National Sugar Co.
Eubanks Carsner, Riverside, Calif.....U. S. D. A.
Orson A. Christensen, Garland, Utah.....Utah-Idaho Sugar Co.
G. E. Classen, Mason City, Iowa.....American Crystal Sugar Co.
Harry Clark, Greeley, Colo.....Mountain States Beet Growers
John E. Clark, Longmont, Colo.....Mountain States Beet Growers
Frank A. Cleland, Missoula, Mont.....American Crystal Sugar Co.
M. S. Clement, Scottsbluff, Nebr.....Great Western Sugar Co.
J. E. Coke, San Francisco, Calif.....Spreckels Sugar Co.
George H. Coons, Beltsville, Md.....U. S. D. A. (Plant Industry Station)
C. E. Cormany, Sheridan, Wyo.....Holly Sugar Corp.
Charles M. Crabtree, Preston, Idaho.....Franklin County Sugar Co.
Clinton Crockett, Pocatello, Idaho.....Kiest Beet Harvester Co., Inc.
George A. Cushman, Minneapolis, Minn.....Sterling Machine Co.
H. W. Dahlberg, Denver, Colo.....Great Western Sugar Co.
Phil Dale, Eaton, Colo.....Great Western Sugar Co.
G. J. Daley, Woodland, Calif.....Grower
M. R. Dalling, Idaho Falls, Idaho.....Utah-Idaho Sugar Co.
A. A. Davis, Lovell, Wyo.....Great Western Sugar Co.
G. W. Deming, Fort Collins, Colo.....U. S. D. A.
J. R. Douglass, Twin Falls, Idaho.....U. S. Bureau of Entomology & Plant Quarantine
A. R. Downie, Rocky Ford, Colo.....American Crystal Sugar Co.
C. W. Doxtator, Rocky Ford, Colo.....American Crystal Sugar Co.
B. E. Easton, Chatham, Ontario, Canada....Canada & Dominion Sugar Co.
J. D. Edmiston, Windsor, Colo.....Great Western Sugar Co.
Curtis V. Edwards, Yakima, Wash.....Lindeman Power Equip. Co.
C. Eliason, Denver, Colo.....Stearns Roger Mfg. Co.
Harold E. Ellison, Layton, Utah.....Layton Sugar Co.
J. Gordon English, Sterling, Colo.....Great Western Sugar Co.
Arthur Eskelsen, West Jordan, Utah.....Utah-Idaho Sugar Co.
W. Essenpreis, Denver, Colo.....John Deere Plow Co.
Holger Figge, Denver, Colo.....American Crystal Sugar Co.
Homer L. Fletcher, Chatham, Ontario, Canada....Canada & Dom. Sug. Co.
Charles A. Fort, New Orleans, La.....U. S. D. A.
Donald C. Foster, Ottawa, Ohio.....Buckeye Sugar Co.
M. G. Frakes, Saginaw, Mich.....Michigan Sugar Co.
John Franklin, Denver, Colo.....Minneapolis & Moline Co.
C. R. Fuller, Kansas City, Mo.....John Deere Plow Co.
Robert S. Gaddie, Salt Lake City, Utah.....Utah-Idaho Sugar Co.
Thomas E. Gardiner, Colorado Springs, Colo.....Holly Sugar Corp.
Robert Gardner, Fort Collins, Colo.....Colo. Agric. Experiment Station
John O. Gaskill, Fort Collins, Colo.....U. S. D. A.
Hatler Gearheart, Chinook, Mont.....Utah-Idaho Sugar Co.
Ned Gearheart, Belle Fourche, So. Dak.....Utah-Idaho Sugar Co.
Gerald Geraldson, Rockford, Ill.....J. I. Case Co.
Fred W. Gettel, Findlay, Ohio.....Great Lakes Sugar Co.
A. M. Ginn, Bayard, Nebr.....Great Western Sugar Co.

G. C. Gordon, Rio Vista, Calif.....Gordon-Hansen Co., Ltd.
Wharton K. Gray, San Francisco, Calif.....Spreckels Sugar Co.
Jesse Green, Anaconda, Mont.....Anaconda Co.
P. M. Grissinger, Ovid, Colo.....Great Western Sugar Co.
D. L. Gross, Lincoln, Nebr.....University of Nebraska
C. E. Guelle, Chicago, Ill.....International Harvester Co.
Edward A. Haagensen, New York City, N. Y.....Dorr Co.
Jay L. Haddock, Logan, Utah.....Utah Agric. Experiment Station
Howard E. Hall, Boise, Idaho.....Olson Mfg. Co.
W. S. Hallam, Colorado Springs, Colo.....Holly Sugar Corp.
R. E. Ham, Garden City, Kans.....Garden City Co.
Clarence Hansen, E. Lansing, Mich.....Michigan State College
Wayne C. Hansen, Preston, Idaho.....Franklin County Sugar Co.
D. Stanford Harris, Layton, Utah.....Layton Sugar Co.
Lionel Harris, Mitchell, Nebr.....U. S. D. A.
Jim D. Hawkins, Garden City, Kans.....Garden City Co.
W. D. Hay, Sacramento, Calif.....U. S. D. A.
M. E. Headrick, Boise, Idaho.....Olson Mfg. Co.
H. H. Heilman, Blissfield, Mich.....Great Lakes Sugar Co.
A. H. Heldt, Scottsbluff, Nebr.....Great Western Sugar Co.
Robert W. Henderson, Univ. Farm, St. Paul, Minn.....U. S. D. A.
A. K. Hepperly, Denver, Colo.....C. B. & Q. R. R.
J. C. Hickenlooper, Preston, Idaho.....Franklin County Sugar Co.
K. W. Hill, Lethbridge, Alberta, Can.....Dominion Experiment Sta.
Orin A. Hills, Phoenix, Ariz.....U. S. D. A.
George B. Holmes, Longmont, Colo.....Great Western Sugar Co.
Lester J. Holmes, Clarksburg, Calif.....American Crystal Sugar Co.
G. W. Howard, Fort Collins, Colo.....Beet Sugar Development Foun.
R. L. Howard, Toppenish, Wash.....Utah-Idaho Sugar Co.
J. R. Hughes, Arvada, Colo.....Simplot Fertilizer Sales Co.
Albert Isaksson, Longmont, Colo.....Great Western Sugar Co.
J. E. Jarrell, Brighton, Colo.....Great Western Sugar Co.
J. F. Jarrell, Longmont, Colo.....Great Western Sugar Co.
Moroni Jensen, St. George, Utah.....Utah-Idaho Sugar Co.
Vernal Jensen, Ogden, Utah.....Amalgamated Sugar Co.
A. N. Johnson, Betteravia, Calif.....Union Sugar Co.
C. F. Johnson, Brighton, Colo.....Great Western Sugar Co.
Harvey P. Johnson, Fort Collins, Colo.....Beet Sugar Development Foun.
Ronald C. Johnson, Salt Lake City, Utah.....Utah-Idaho Sugar Co.
R. A. Jones, Anaconda, Mont.....Anaconda Copper Mining Co.
Albert M. Jongeneel, Walnut Grove, Calif.....Marbeet
A. C. Joost, Fremont, Ohio.....Great Lakes Sugar Co.
H. Juergens, Mitchell, Nebr.....Great Western Sugar Co.
Curzon Kay, Clarksburg, Calif.....American Crystal Sugar Co.
J. C. Keane, Salt Lake City, Utah.....Utah-Idaho Sugar Co.
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J. W. Kenney, Walteria, Calif.....Dicalite Co.
R. L. Kimmons, Greeley, Colo.....Great Western Sugar Co.

George H. King, Ogden, Utah.....Layton Sugar Co.
K. H. Klages, Moscow, Idaho.....University of Idaho
H. J. Klinge, Preston, Idaho.....Franklin County Sugar Co.
H. E. Knapp, Rocky Ford, Colo.....American Crystal Sugar Co.
H. L. Kohls, E. Lansing, Mich.....Michigan State College
C. R. Koontz, Fort Morgan, Colo.....Great Western Sugar Co.
Albert J. Krause, Fort Collins, Colo.....Colorado A & M College
Ervin P. Krause, Fort Collins, Colo.....Colorado A & M College
Alvin Krey, Sidney, Mont.....Holly Sugar Corp.
G. M. Kriegbaum, Richmond, Ind.....International Harvester Co.
R. S. Lambdin, Spreckels, Calif.....Spreckels Sugar Co.
John Landysheff, Raymond, Alberta, Can.....Canadian Sugar Fac., Ltd.
L. D. Leach, Davis, Calif.....University of California
F. H. Leavitt, San Francisco, Calif.....Shell Chemical Corp.
Jared Lewis, Preston, Idaho.....Franklin County Sugar Co.
Rulon D. Lewis, Salt Lake City, Utah.....Bureau of Reclamaton
Stanley Lewis, Rigby, Idaho.....Utah-Idaho Sugar Co.
E. E. Ludwig, Garden City, Kans.....Garden City Co.
Gordon Lyons, Stockton, Calif.....California Beet Growers Assn.
D. M. MacAulay, Fort Garry, Manitoba, Can.....Manitoba Sugar Co., Ltd.
L. S. MacDonald, Missoula, Mont.....Northern Pacific Railway Co.
C. V. Maddux, Denver, Colo.....Great Western Sugar Co.
Charles F. Mann, Billings, Mont.....Great Western Sugar Co.
Guy D. Manuel, Sacramento, Calif.....Spreckels Sugar Co.
R. E. Marsh, Windsor, Colo.....Great Western Sugar Co.
Earl Q. Marsing, Nampa, Idaho.....Amalgamated Sugar Co.
John E. Mason, Denver, Colo.....Sterns Roger Mfg. Co.
J. R. Mason, Denver, Colo.....Great Western Sugar Co.
A. A. Mast, Phoenix, Ariz.....Western Seed Production Corp.
E. J. Maynard, Denver, Colo.....Great Western Sugar Co.
G. B. Mayo, Garden City, Kans.....Grower
S. W. McBirney, Fort Collins, Colo.....U. S. D. A.
J. D. McCague, Yakima, Wash.....Lindeman Power Equipment Co.
M. E. McCollam, San Jose, Calif.....American Potash Inst.
N. R. McCreery, Denver, Colo.....Great Western Sugar Co.
Kathleen McKillen, Los Angeles, Calif.....Ransom Seed Laboratory
P. H. McMaster, Scottsbluff, Nebr.....Great Western Sugar Co.
V. A. Meek, Grand Junction, Colo.....Holly Sugar Corp.
I. H. Mercer, Denver, Colo.....Minneapolis-Moline Co.
E. M. Mervine, Fort Collins, Colo.....Colorado Agric. Experiment Sta.
D. M. Mims, Garden City, Kans.....Garden City Co.
Paul E. Milton, Johnstown, Colo.....(Demonstrating Planters)
Donald S. Mitchell, Denver, Colo.....U. S. Bureau of Reclamation
William R. Monette, Los Angeles, Calif.....Dicalite Co.
Ray M. Moreland, Sugar City, Colo.....National Sugar Mfg. Co.
W. B. Morrow, Las Cruces, N. Mexico.....Western Seed Production Corp.
O. P. Mortensen, Sugar City, Idaho.....Utah-Idaho Sugar Co.
Albert M. Murphy, Twin Falls, Idaho.....U. S. D. A.
M. A. Myers, Garden City, Kans.....Grower
A. R. Nees, Denver, Colo.....Great Western Sugar Co.

Ray E. Neidig, San Francisco, Calif.....Cons. Mining & Smelting Co. of Canada, Ltd.
M. H. Nelson, Longmont, Colo.....Great Western Sugar Co.
Russell T. Nelson, Longmont, Colo.....Great Western Sugar Co.
W. D. Nicholson, Wheatland, Wyo.....Great Western Sugar Co.
John C. Nigro, Swink, Colo.....Holly Sugar Corp.
S. B. Nuckols, Scottsbluff, Nebr.....U. S. D. A.
E. O. Nunn, Garden City, Kans.....McCoy Motor Co.
W. J. O'Bryant, Spanish Fork, Utah.....Utah-Idaho Sugar Co.
L. F. Odette, Garden City, Kans.....Garden City Co.
Chase Oftedal, Ronan, Mont.....American Crystal Sugar Co.
Harold R. Olsen, Preston, Idaho.....Franklin County Sugar Co.
Sidney J. Osborn, Denver, Colo.....Great Western Sugar Co.
F. V. Owen, Salt Lake Ciy, Utah.....U. S. D. A.
A. E. Palmer, Lethbridge, Alberta, Can.....Dominion Experiment Station
Rulon R. Parks, Blackfoot, Idaho.....Utah-Idaho Sugar Co.
R. L. Partridge, Fort Collins, Colo.....Great Western Sugar Co.
E. P. Pattison, Colorado Springs, Colo.....Holly Sugar Corp.
Ray A. Pendleton, Corvallis, Oregon.....U. S. D. A.
John D. Petrikin, Brush, Colo.....Great Western Sugar Co.
R. F. Phillips, New York City, N. Y.....Sugar Research Foundation
L. T. Pierce, Billings, Mont.....U. S. Weather Bureau
J. B. Powers, Davis, Calif.....University of California
LeRoy Powers, Cheyenne, Wyo.....Cheyenne Experiment Station
A. G. Quamme, Mason City, Iowa.....American Crystal Sugar Co.
Otto Quast, Corvallis, Mont.....Grower
A. D. Ramsey, Garden City, Kans.....Garden City Co.
J. F. Rasmussen, Denver, Colo.....(Consulting Engineer for Nat'l Sugar Mfg. Co.)
B. W. Reading, Fremont, Ohio.....Freemont Beet Growers Ass'n.
George O. Reed, Ovid, Colo.....Great Western Sugar Co.
Perc A. Reeve, Saginaw,Mich.....Farmers & Mfgrs. Beet Sugar Ass'n.
Carl Reinsch, Bay City, Mich.....Monitor Sugar Co.
W. J. Resch, San Francisco, Calif.....Spreckels Sugar Co.
Nelson E. Reynolds, Detroit, Mich.....Harry Ferguson, Inc.
Quince Rice, Boise, Idaho.....U. S. D. A.
D. J. Roach, Denver, Colo.....Great Western Sugar Co.
D. W. Robertson, Fort Collins, Colo.....U. S. D. A.
Paul T. Robinson, Chaska, Minn.....American Crystal Sugar Co.
Elizabeth Roboz, Laramie, Wyo.....University of Wyoming
Robert Rodgers, Salt Lake City, Utah.....Utah-Idaho Sugar Co.
J. W. Rooney, Oxnard, Calif.....American Crystal Sugar Co.
Frank L. Rouse, Hamilton, Mont.....Bell Holt McCall Co.
Easborn Rusco, Moline, Ill.....Minneapolis-Moline Imp. Co.
George K. Ryser, Salt Lake City, Utah.....U. S. D. A.
H. J. Sanders, Gunnison, Utah.....Gunnison Sugar, Inc.
H. B. Saxton, Longmont, Colo.....Great Western Sugar Co.
Ford T. Scalley, Belle Fourche, So. Dak.....Utah-Idaho Sugar Co.
Paul D. Scalley, Idaho Falls, Idaho.....Utah-Idaho Sugar Co.
W. D. Scharton, Sugar City, Colo.....National Sugar Mfg. Co.

K. Schreiber, Fort Garry, Manitoba, Can.....Manitoba Sugar Co., Ltd.
Paul R. Schroeppel, Rockford, Ill.....J. I. Case Co.
A. A. Schupp, Saginaw, Mich.....Farmers & Mfgrs. Beet Sugar Assn.
George Schwarz, Green Bay, Wisc.....Menominee Sugar Co.
E. W. Shannon, Longmont, Colo.....Great Western Sugar Co.
B. T. Shaw, Beltsville, Md.....U. S. D. A.
A. W. Skuderna, Denver, Colo.....American Crystal Sugar Co.
Lorin E. Smith, E. Lansing, Mich.....U. S. D. A.
Paul M. Smith, Eaton, Colo.....Great Western Sugar Co.
Paul K. Smith, Preston, Idaho.....Franklin County Sugar Co.
Phillip B. Smith, Fort Collins, Colo.....Beet Sugar Development Foun.
R. J. Smith, Colorado Springs, Colo.....Holly Sugar Corp.
Wesley Smith, Taber, Alberta, Canada.....Canadian Sugar Factories, Ltd.
J. Gerald Snow, Lethbridge, Alberta, Can.....Canadian Sugar Factories, Ltd.
George R. Stafford, Fort Collins, Colo.....U. S. D. A.
A. B. Stephan, Longmont, Colo.....Great Western Sugar Co.
John Stewart, Brighton, Colo.....Great Western Sugar Co.
Eugene Stoeckly, Garden City, Kans.....Garden City Co.
Myron Stout, Salt Lake City, Utah.....U. S. D. A.
J. A. Swanson, Denver, Colo.....J. I. Case Co.
Edward L. Swift, Hamilton, Mont.....American Crystal Sugar Co.
Edwin M. Swift.....American Crystal Sugar Co.
Jerre F. Swink, Rocky Ford, Colo.....American Crystal Sugar Co.
Jack C. Tanner, E. Grand Forks, Minn.....American Crystal Sugar Co.
E. V. Taylor, Fountain, Colo.....Holly Sugar Corp.
Frank R. Taylor, Raymond, Alberta, Canada....Canadian Sugar Fact., Ltd.
Gerald Thorne, Salt Lake City, Utah.....U. S. D. A.
Bruce J. Thornton, Fort Collins, Colo.....State Seed Labortary
R. J. Tingley, Stockton, Calif.....Holly Sugar Corp.
Bion Tolman, Salt Lake City, Utah.....Utah-Idaho Sugar Co.
Russell T. Tutt, Garden City, Kans.....Garden City Co.
Wm. E. Urschel, Valparaiso, Ind.....Scott Viner Co.
Andrew VanHook, Laramie, Wyo.....University of Wyoming
H. S. Varner, Longmont, Colo.....Great Western Sugar Co.
H. S. Varner, Jr., Denver, Colo.....Bureau of Reclamation
Phelps Vogelsang, Midland, Mich.....Dow Chemical Co.
Russell S. Wait, Croswell, Mich.....Michigan Sugar Co.
H. B. Walker, Davis, Calif.....University of California
W. E. Walters, Windsor, Colo.....Great Western Sugar Co.
H. C. Watts, Chicago, Ill.....International Harvester Co.
Boyd Webb, Chinook, Mont.....Utah-Idaho Sugar Co.
F. W. Weitz, Oxnard, Calif.....American Crystal Sugar Co.
Frank Whiting, Loveland, Colo.....Great Western Sugar Co.
J. L. Williams, Fort Morgan Colo.....Great Western Sugar Co.
C. R. Wing, Raymond, Alberta, Can.....Canadian Sugar Factories, Ltd.
J. S. Witherow, Fort Lupton, Colo.....Great Western Sugar Co.
E. W. Witkowski, Denver, Colo.....John Deere Plow Co.
J. Arthur Wood, Salt Lake City, Utah.....Utah-Idaho Sugar Co.
R. C. Wood, Safford, Ariz.....Western Seed Production Corp.
R. R. Wood, Billings, Mont.....Great Western Sugar Co.

T. George Wood, Raymond, Alberta, Can.....Canadian Sugar Factories, Ltd.
F. W. Woods, Swink, Colo.....Holly Sugar Corp.
Guy O. Woodward, Preston, Idaho.....Franklin Co. Sugar Co.
J. L. Wursten,Pocatello, Idaho.....Simplot Fertilizer Sales Co.
W. H. Ziegler, Stockton, Calif.....Holly Sugar Corp.
Ellen Zink, Fort Collins, Colo.....State Seed Laboratory
C. H. Zirckel, Chicago, Ill.....International Harvester Co.
H. E. Zitkowski, Denver, Colo.....American Crystal Sugar Co.
Henry D. Zobell, Nyssa, Oregon.....Amalgamated Sugar Co.